THE

JOURNAL
OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Published by the Society of Automotive Engineers, Inc., 29 *W.* 39*th St., New York*

Issued monthly, 50 cents a number, $5 a year; foreign $6 a year; to members, 25 cents a number, $2.50 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1918.

David Beecroft, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, *Treasurer*

Vol. X JANUARY, 1922 295504 No. 1

INDEX

Activities of the Sections		72
Applicants for Membership		75
Applicants Qualified		76
Atoms		62
Balloon Instruments and Methods		61
Bomb Dropping		63
Business Cycle		52
Chicago Fuel Session		1
Chrome-Molybdenum-Steel Applications from the Consumer's Viewpoint — C N Dawe		47
Continuous Die Rolling — G R Norton		43
Current Standardization Work		69
December Council Meeting		11
Engineering Education		41
Engineers as Managers		16
Manufacture and Application of Automobile Varnishes and Paints — L Valentine Pulsifer		12
Marketing Grain		41
Mechanical Inspection in Export Trade		64
Methods of Measuring Detonation in Engines — Thomas Midgley, Jr, and T A Boyd		7
Personal Notes of the Members	Adv Section	2
Pertinent Facts Concerning Malleable-Iron Castings — Enrique Touceda		53
Publications of Interest to S A E Members		73
Railroad Electrification		42
Service		68
Total Sensible Heats of Engine Fuels and Their Mixtures with Air — R E Wilson and D P Barnard, 4th		65
Trend of Aviation Development — J G Vincent		25
Truth About Commercial Aviation		51
Viscosity and Friction — Winslow H Herschel		31
Men Available	Adv Section	46
Positions Available	Adv Section	56

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. X January, 1922 No. 1

Chicago Fuel Session

THE joint sessions in which representatives of the Society, the National Automobile Chamber of Commerce and other automotive interests conferred with members of the American Petroleum Institute at Chicago on Dec. 6 and 7 represent one of the results of consistent effort on the part of leading men in the automotive and the oil industries for the past 2 years to bring about a closer understanding and more active cooperation between these two industries in reaching solutions of some of the immensely important problems in which their interests and those of the general public are involved.

The keynote of the sessions was the necessity and practicability of uniformity and sufficient volatility of gasoline as marketed and used for motor fuel throughout the Country. After a presentation of the general economic situation by Dr. Van H. Manning for the petroleum industry and Edward S. Jordan for the automotive industry, the technical phases of the problem were discussed from various angles in a series of papers that appear hereinbelow in abstract form.

The success of the meeting in bringing about a better understanding of the real problems and difficulties of each industry by representatives of the other was obvious throughout. It was evident that a status has been reached wherein neither the petroleum refiner nor the automotive engineer is willing to speak before a technical audience without considering carefully whether his statements will stand analysis in the light of the practical limitations of the other industry.

The automotive engineer has of necessity studied the problem of proper utilization of available fuels; it was a part of his job. Therefore, prior to a recent date the problems of decreasing volatility and lack of uniformity received more attention from him than from the fuel producer. Of late there has been a rapidly increasing interest in this problem on the part of the petroleum industry, this being accompanied by gratifying research activity. The Chicago meeting constituted a conspicuous step in advance in the growing spirit of mutual understanding and cooperation between the two great industries. The technical men in them are being brought together in intimate professional discussion.

R. D. Benson, president of the Tide Water Oil Co., and Capt. J. F. Lucey, president of the Lucey Mfg. Co., had charge of the deliberations of the sessions, and as executives favored strongly the continuance of further and more intensive engineering work in the field of oil technology. It was seen how very great the need is for research in the realm of oil refining. This point was driven home by Sir John Cadman, formerly His Majesty's Petroleum Executive. The matter was stressed also by President Beecroft, of the Society.

EDWARD S. JORDAN

Mr. Jordan, president of the Jordan Motor Car Co., presented on behalf of the National Automobile Chamber of Commerce a statement as to the public's attitude toward the automobile industry and toward the little understood fuel problem, in the working out of which the engineers have had little consideration from many of the automobile producers. His address was in part as follows.

It has been said that five things are vitally essential to the welfare of the people and the progress of the Nation. The first four, food, fuel, clothing and shelter, are really necessary to life, but the distribution and general enjoyment of them depend absolutely upon the fifth, transportation.

Some of you represent an industry engaged in producing fuel. I represent an industry engaged in producing transportation. Our interests are mutual and our common obligation to the public is identical.

I have an impression that the oil industry has suffered in somewhat the same way the automobile industry has suffered, through prosperity. Engineers in our industry will tell you that the manufacturers have been so successful in past years in building what they chose to build, that they have not been careful to keep in touch with all of the engineering developments. Many of the companies have not spent much money in research work. I think that the present conditions will bring about a greater appreciation of the necessity for cooperative research work in our industry and in yours. I wish to present a certain point of view, which might be said to be a sales or a service point of view, based upon our mutual obligation to the man who is going to determine whether we can market our product and how we shall market and what price we will get for it—the owner of the automobile.

MORE EFFICIENT CARS

There is a very strong tendency among manufacturers to direct their engineers to build lighter or at least more economical, more efficient cars. That is the first consideration today. It indicates an acceptance on the part of

automobile manufacturers of the fundamental need of the owner, a vehicle of necessary transportation that can be operated at the lowest possible cost.

A misapprehension still exists in the minds of many that people do not care how much they pay for service, whether it pertains to weight, tires, gasoline or upkeep. They do care, because they have passed the social stage, I may say, in the appreciation of the automobile. They are now on a practical day-in and day-out service basis. We believe that this movement, which is fostered and being promoted very energetically by the Society of Automotive Engineers, will be acquiesced in and adopted by the manufacturers, not because they merely desire to improve automobiles, but because they want to maintain their volume of production and build their business. There will be a very strong movement toward more efficient, more economical cars.

Better Gasoline Wanted

During the past 10 months I have visited every State in the Union except two. I have talked with thousands of automobile dealers, owners, salesmen and service-men. The producers of automobiles and the producers of fuel should realize that there is a very insistent demand on the part of the public for what it calls a better grade of gasoline. The engineers might say a more standard grade of gasoline. I do believe that the public is demanding not so much a lower price for gasoline as a more efficient kind of service from the gasoline used. We hear the demand everywhere, and I think it should be recognized.

We hear frequently now that the automobile industry is not growing, and that possibly we will not need so much fuel in the future as we have thought we would need. It is our belief that the so-called saturation-point will never be reached until every place in the civilized world is united to every other place by some unit of transportation, and that the passenger car of the future will serve as a very important part of that system. The future of the motor truck is, in my opinion, almost beyond our comprehension.

What Increased Efficiency Would Mean

The question of economy in design and operation is becoming more and more acute and widely talked about. There are 4,000,000 Fords in this Country. Assuming that every Ford owner drives his car 5000 miles a year we have a total of 20,000,000,000 miles per year. At 20 miles per gal., the consumption would be 1,000,000,000 gal. At 20 cents per gal., which is low, the total cost would be $200,000,000. Now if a saving of 10 per cent could be made by the joint efforts of the engineers building motor cars, the carbureter designers and the fuel producers, it would mean $20,000,000 to Ford owners, which would mean the sale of 40,000 more Fords, and the consumption of more gas. Naturally I take the sales point of view. All good merchandisers recognize the fact that volume at a low margin is more profitable than a smaller volume at a higher price.

The Yellow Taxicab Co. of Chicago operates 1300 cabs. It uses 350,000 gal. of "gas" per month. It is now manufacturing its own gas. At 20 cents per gallon that amounts to $840,000 per year. A saving of 1 cent per gal. would mean $42,000, or the equivalent of 210,000 miles of service.

I mention the figures relating to Fords and Ford owners, and to the Yellow Taxicab Co., because they serve as concrete illustrations of what it would mean to all of the car owners in the United States, if some small increase, some small percentage of improvement, were made in the efficiency of motor cars.

There is a very insistent demand on the part of mechanics all over the Country for better gas, as they say, or a more standard grade of gas. One engineer told me about having to take down the engine of one of the best cars built every fifteen thousand miles to repair the damage that had been done by poor gas, rotten gas as he called it.

There are 10,000,000 people in this Country using your product and our product. We are selling your product as well as our own. We have reached the conclusion that if we render better service our product will be sold more effectively; and that our volume of business and profits will be increased, if we strive with might and main to improve the character of our product.

We of the National Automobile Chamber of Commerce have great respect for your organization. You represent in your own industry about the same thing that we represent in ours. You have here today some very able men representing the Society of Automotive Engineers and various departments of the Government, and others well qualified to be of assistance to our industry and to yours in promoting research work which will help us meet this situation. The manufacturers of motor cars are sincerely anxious that the American Petroleum Institute accept this offer of cooperation. It will be fulfilled in spirit and deed. We hope that out of this gathering will come some definite expression or some definite practical effort toward the solution of the fuel problem.

H. M. CRANE

The first spokesman of the Society at the sessions was H. M. Crane, the chairman of its Research Committee. His topic was the requirements of motor-vehicle fuel. He pointed out that the growth of the automotive industry in its present form was made possible by a plentiful supply of a volatile fuel, the original 76-deg. gasoline. In spite of economic pressure for 20 years toward the use of kerosene, the public is still willing to pay twice as much for gasoline, proving its greater "utilization value" in the class of motor-car equipment that has proved practical. Engineers have learned to design equipment to use heavier and heavier fuels but there is a limit beyond which this cannot go. Some portions of the worst fuels now marketed have practically no utilization value at all in present classes of equipment and might better be thrown away. Uniformity in fuels marketed in the same territory would be an aid to economy and efficient utilization. More volatile fuels in winter than in summer, and in the colder than in the warmer parts of the Country, are desirable both for the refiner and for the user.

N. A. C. SMITH

An exposition of the volatility of motor fuel as marketed in the United States was given by N. A. C. Smith, petroleum chemist of the Bureau of Mines, which has made periodic surveys of the motor-fuel supplies marketed throughout the Country in 1915, 1917, 1919, 1920 and 1921. He summarized the results of tests of volatility to show: (*a*) periodic changes in volatility and (*b*) variations between fuels from different companies marketed simultaneously in the same territories. The end-point was taken as the criterion of volatility and it was shown that the average end-point has risen steadily from about 370 deg. fahr. in 1915 to about 445 deg. in 1920, with a slight drop in 1921. The average end-point of the least volatile 10 per cent of the fuels was compared with that of the 10 per cent most volatile fuels. The differ-

ence between these was a maximum of 110 deg. fahr. in 1919, and has been growing somewhat less, from which Mr. Smith concluded that there is a natural trend toward greater uniformity in motor fuels marketed by different companies.

F. A. HOWARD

The qualitative limitations in refining and marketing were discussed by F. A. Howard, manager of the development department of the Standard Oil Co. of New Jersey. He enumerated the possible limitations in refining of motor fuel as: (*a*) heating value, (*b*) volatility, (*c*) purity and stability and (*d*) combustion characteristics. He showed that, for practical purposes, volatility alone imposes any real limitation on fuels produced from sources at present available. The present Government-specification gasoline was referred to as two parts head, seven parts body and one part tail; while the available supply of crude includes about 35 parts tail, most of which have to be marketed in the form of other products. Marketing limitations are volatility and susceptibility to water. It is impossible to market by present methods a fuel of too low a boiling-point or one that is injured by the presence of small amounts of water. The present marketing system cannot handle different grades of fuel without adding greatly to the cost; it tends therefore to uniformity. Gasoline as a primary fuel must be produced at a minimum of labor costs, as its function is to conserve labor.

F. C. MOCK

The limitations imposed on economy by volatility changes in motor fuel were outlined by F. C. Mock, research engineer of the Stromberg Motor Devices Co. He characterized the intake system of the automobile engine as a still in which the liquid is metered continually at the intake end, the behavior of the engine depending, however, upon the amounts of vapor at the outlet end. Most of the difficulties in carburetion arise from the nature of this still system when applied to less and less volatile fuels. The engine and the carbureting system have been improved to meet the changing quality of fuels but this does not apply to cars that have been in use for several years. In particular, the high-grade cars, which do not wear out quickly, are compelled to operate much of the time with fuels for which they are not adapted. The motor fuels marketed have ranged from too volatile to operate in summer to those that could not be lighted with a match at 5 deg. fahr. While some variations may be necessary and desirable, there should be a recognized standard, and variation from it should be clearly specified as such.

C. K. FRANCIS

In the matter of the extent and causes of the present variations in the quality of motor fuel, C. K. Francis, chief chemist of Cosden & Co, took the ground that the demands of the public which the engineer attempts to meet are for speed and "pep," without much regard to how these are secured. The status of gasoline has changed in 20 years from that of an almost worthless nuisance to a product of prime importance in the petroleum output. The accepted laboratory tests for motor fuel were discussed by Mr. Francis in some detail.

Gravity is no longer considered an index of quality, since, with the advent of a wide variety of crude oils, there is no longer any definite relationship between specific gravity and any other important property of gasoline.

The tests for sulphur-content are not yet entirely satisfactory. Sulphur compounds in general must be removed to prevent corrosion and present refining processes are quite capable of accomplishing this. Better methods of test are being developed. Mr. Francis stated that free sulphur present to the extent of 0.008 per cent is deleterious and larger amounts are very bad.

The presence of unsaturated compounds is not detrimental in itself but under some conditions, not yet very well under control, these compounds may lead to the formation of gummy compounds that are very objectionable. Gasoline should be entirely free from acid and can be so produced without difficulty.

The total available energy of all gasolines as represented by their heats of combustion does not vary more than a few per cent from 20,000 B.t.u. per lb. The energy per gallon is greater for the heavier fuels.

The distillation curve representing the volatility of the gasoline is a measure of its "pep," the quality most desired by the average user; and volatility is the most important of the laboratory tests. Most gasolines are marketed today at wholesale on a volatility basis and the distillation characteristics of the product reaching the consumer are secured by blending, in which very volatile casinghead gasoline plays an important part. There is no real definition of what gasoline really is. With regard to the marketing of several different grades, Mr. Francis asked, With a more exact knowledge of the uses to which a gasoline is to be put, is it not possible to imagine that several grades of gasoline should be sold at the filling station? The present practice, at least in many places, is to put the same gasoline into a Ford that goes into a Locomobile.

Mr. Francis warned against too close specifications for gasoline. He maintained that the present Government specifications are so close as to limit the output of the smaller refiners and that the general adoption of such rigid specifications would be a hardship on them and increase the price to the public.

O. C. BERRY

With relation to the practical effects of too low volatility, O. C. Berry, chief engineer of the Wheeler-Schebler Carburetor Co., drew a distinction between the results obtainable in the use of present-day fuels under experimental conditions and those secured in practice, and pointed out the reasons for this difference. It has been impossible for the engineer to put into the hands of the public an engine that will utilize present fuels without serious difficulty and waste, and any further decrease in volatility would decrease the usefulness of the 10,000,000 vehicles now in use. The automotive engineers are making every effort to remedy this situation and it can be expected that they will find means in the near future for producing engines that will use present and even heavier fuels with entire satisfaction, but until that time the petroleum refiners are urged to make no further reduction in the volatility of commercial motor fuel.

PRESIDENT BEECROFT

Research work is necessary at this time when the attention of the world is focused on the subject of greater efficiency and economy. In the earlier days of our industries it was not a necessity; today it is obviously a necessity. I regret that the executives of the great petroleum industry of this Country and the executives of the various groups constituting the automotive industries are not meeting together to discuss a common research program.

The Society of Automotive Engineers is keenly appreciative of the spirit of cooperation manifested last year at the Washington meeting of the American Petroleum

Institute, and again this year by your invitation to us to participate extensively in the sessions now being held. We recognize that your request for cooperation has been prompted by a clear conception of the relationships that exist between you, the producers of the fuel for the internal-combustion engine, and us, the designers of the engines and vehicles that must use the fuel.

We express the sincerest hope that we shall approach nearer and nearer to the eventual goal both of us are seeking. The Society has been considering the fuel problem at its semi-annual meetings for several years and we ask that the engineers representing your industry meet with us in increasing numbers. We solicit their membership in our Society on the basis that only by the closest cooperation of the two groups of engineers will the results be accomplished that the exigencies of the time call for.

The world will use all forms of automotive apparatus if we can make them suitable in design and operation for its needs and capacities. It is not so much a question of where the market is as of adapting the vehicle and its fuel to the possible owner. We have but one aim, and it is common to our two organizations; namely, to design the vehicles and fuels to permit of purchasing, operating and maintaining the vehicles at the lowest cost. With another mutual aim we would be erecting barriers to sales, making it more difficult for the peoples of the world to own, operate and maintain our apparatus.

America has been and is the greatest world producer of petroleum products. America has been and is the greatest producing nation of automotive vehicles. Fairly reliable statistics show that while we have approximately 10,000,000 motor vehicles in this Country, there are approximately 1,000,000 in the other parts of the world. Let us not lose sight of the fact that the world is our market and that we must set our houses in order to meet it.

Early this year our Society created a research department which had its inception nearly 2 years ago in the fuel problem that we are discussing today. We are not creating a special laboratory to carry on research work, but are cooperating with Government laboratories, such as the Bureau of Standards and the Bureau of Mines, with university laboratories and with the laboratories of companies in the various automotive industries represented in the membership of the Society. We expect this research work to become one of the major activities of the Society, not second to the standardization work that we have carried on for over 10 years and that has made the great development of the automotive industry possible.

We believe that a combined research program of your industry and our Society on the internal-combustion engine fuel program is most desirable, and look forward to the time when the expense of the work now defrayed from the regular funds of your Institute and our Society, will be borne by appropriations or endowments that will place the work on the plane that the necessities of the case demand.

CHAIRMAN LUCEY

We who are in the practical end of the petroleum industry would like to take Mr. Beecroft's little speech, take out the words "automotive engineers" and simply substitute "the oil industry." The speech would apply just the same.

In my own experience in contact with engineers, I find that, contrary to the general thought expressed, they are not theoretical but intensely practical. They have no more time for the theorists than we have. We have with us a man who contributed much in the great war. He is very much interested in the subject we are discussing, having been the founder of one of the courses in connection with the study of the oil problem in a principal college in England, and having headed the petroleum industry for his Government during the war. I thought you would all like to have the opportunity of meeting Sir John Cadman.

SIR JOHN CADMAN

If there was ever evidence of the importance, the desirability and the necessity of scientific research in these great industries, it is the evidence of what we have heard this morning. When I heard the illuminating papers that were presented by men of knowledge on the subject, as a petroleum technologist my scientific conscience almost made me shout, "Atta boy!" I believe that the great internal-combustion engine industry has got to force scientific ability in the research upon this most important petroleum problem.

On the other hand, I am sensitive of the fact that the automobile engineers also realize that if they are to carry on their industry and if they are unable to force the petroleum industry into giving them those beautiful homogeneous products that they appear to desire, they must make the design of their machines so elastic that they can use efficiently without that 25-per cent loss of which we have heard, the product that the oil industry in its judgment feels that it can give.

There are a great many important problems in this connection that all of us must bear in mind. We must bring knowledge to bear upon the component parts of the product with which we are working. I do not wish to belittle in any way the great work that has already been done. The demand upon the industries has been so great that to my mind it is extraordinary that they have been able to rise to the occasion and provide the great quantity of products which you are using. But knowledge demands a further inroad into the base of this product. The realm of the physicist, the activity of the chemist and the ingenuity of the engineer are all required. What we want to know is the actual structure of the molecule that is really the primary base of this product; and when we know its structure, we have got to find out how we can handle that molecule and make it behave in the way we please. We must learn how we can add another atom of hydrogen, chiefly. That is in the realm of abstruse science; it is the real science; the subject may take years to fathom. But I believe that with the aid of the great geniuses of this Country the problem will be solved. When it is solved, the automobile engineers will be able to get exactly what they want, a homogeneous product of a molecular structure giving a possibility of bringing about combustion without any losses. Then, in truth, the activities of this great body and its sister body, the Society of Automotive Engineers, will have solved one of the great problems which they face.

O. P. KEENEY[1]

I would like to discuss very briefly the value of research work to the sales department. In a period of large stocks and diminished demand, a sales department is more than just an order-taking department, and its problems get more attention then though not more than they deserve all the time. There is a form of research that is

[1] Manager of the paraffin and lubricating sales and bulk sales departments, Tide Water Oil Co., New York City.

always important to a sales department and particularly valuable during a time of uncertain prices and difficulty in keeping the refinery storage-tanks from overflowing. It is of great importance to all phases of the industry. It has to do with the standardization of tests and testing-methods. As this research is done efficiently and uniform testing methods are evolved and put into practice, we shall see the approach of the millennium for the oil salesmen, when goods once sold will stay sold and at the price originally agreed upon; when no telegrams will be received during a falling market, such as, "Your tank-car of lubricating oil held on demurrage, not up to specifications, will unload at reduced price."

Uniform Testing-Methods

When a shipment is received and tested by a buyer, he may not use the same type of instrument or may interpret the results differently, and the chance for a most unsatisfactory dispute arises, more unsatisfactory even than the cost of demurrage or a double transportation-cost. Testing-methods and specifications are two different subjects, and I want to plead the cause of research work that will evolve and make possible the putting into actual everyday use of uniform testing-methods.

The gentlemen present representing the automotive industry are, I believe, vitally interested in this problem. They are concerned with the problem of uniformity of motor fuel. How can this be solved when the refiner and the purchaser of gasoline in describing a product can use the same general terms and each in reality mean to describe an essentially different product, because they make the same tests in different ways. I think I need not elaborate on the necessity or economy of uniformity in testing-methods. The only difficulty is in getting something done about it. After much discussion and thought, many people feel that just one thing more is necessary to have this long-contemplated ideal have the chance of becoming a reality. That is for the American Petroleum Institute to operate a research laboratory equipped to do referee testing work. This would not be an unnecessary duplication of any existing laboratory. No refinery laboratory can fulfil this function; the law prevents the Government bureaus from doing it; the commercial laboratories would be more profitable and useful if they could guarantee their work to check with this referee testing laboratory. This laboratory could also do absolutely necessary research work. The expense to the Institute need not be large, as the fees for work and for issuing certificates to commercial laboratories should bring in a good revenue. Indeed, I believe that, if necessary, various oil companies or organizations might guarantee in advance to furnish enough work for the first year to pay the running expenses.

There is an almost universal desire for uniformity in testing methods; considerable progress in that direction has been made, but further progress absolutely requires a research laboratory equipped to do referee testing. The American Petroleum Institute is the only logical organization to undertake this work.

Mechanical Standards

J. R. Stockton, vice-president of the Purchasing Agents' Association of Tulsa, Okla., made a strong plea for standardization of parts and fittings in the oil field, *on a national basis by a national organization*, stating that the American Petroleum Institute is the logical body to foster the movement. He said that the need for a broader and more comprehensive standardization had long been recognized, but that those most vitally interested have in this, as in many of their other interests, played the great American game of "passing the buck," losing hundreds of thousands of dollars as a result of this attitude. He explained that purchasing agents, in touch with both their own stocks and those of the supply companies, see this very clearly. The duplication of stocks in the hands of both the producers and the supply companies, which even a little standardization would materially cut down, is enormous. The operating companies have to pay the carrying charges on these stocks, whether they are carried in their warehouses or not. It is only natural, therefore, that there should be much interest in standardization.

A. W. AMBROSE

Discussing petroleum research, A. W. Ambrose, chief petroleum technologist of the Bureau of Mines, gave an interesting account of general and specific problems in this field. Some of the points he made were as follows:

Much research is ultra-scientific and closely associated with theoretical deductions. As a result, some people are inclined to place all research in a class that perhaps can be best described as high-brow work. This possibly accounts for a certain feeling that research work does not tie up with the business end of the industry. This is a mistake, for engineering research and investigation can in many cases be easily translated into large financial returns. Often a piece of work of a few weeks' duration will give results that can be easily measured in dollars and cents. For example, an oil company in the Mid-Continent oil fields approached the Bureau of Mines' field men at Bartlesville, Okla., on a problem of sour gasoline. In less than 1 week tests had been carried on which demonstrated that the gasoline could be made sweet by a treatment costing $0.001 per gal. The company had a production of gasoline of 250,000 gal. per month, and as a result of this 1 week's investigation it sold its gasoline for an additional 3 cents per gal., thus increasing its revenue about $7,500 per month. That is practical research.

There is of course another type of research that extends over a long period of time, but often this furnishes fundamental data that are the basis of further work. It is difficult to show that such work has a money basis but it is there just the same. The petroleum industry needs both the practical type of research concerning the immediate problems at hand and that of a more scientific nature which furnishes fundamental data.

Perhaps the most important problem today is a study of the better utilization of the fuel-oil fraction of our crude oil. Fifty-five to 60 per cent of the crude oil produced in the United States is burned directly under boilers to produce steam, and this percentage indicates the importance of the problem. It seems advisable when we have a limited supply of fuel oil that it should be utilized so as to go around as far as possible. There are many plants where the needed power can be furnished as readily by a Diesel engine as by steam turbines or other forms of steam engine. An ordinary steam-engine power-plant in which fuel oil is burned directly under boilers will have an overall efficiency of from 10 to 12 per cent. If this same fuel oil is used in an internal-combustion engine of the Diesel type, the efficiency will perhaps be as high as 33 per cent. This means that a given amount of fuel oil will yield about three times as much power. The trend at present therefore should be toward the use of Diesel-type engines.

Much oil is needed, however, for use under steam boilers and there is room for improvement in the design

of burners for handling this oil, in both steam atomizing and mechanical burners. The possibilities of such investigative work were indicated when boiler inspectors in California in the service of the United States Fuel Administration demonstrated that fuel-oil consumption of almost every plant inspected could be reduced from 5 to 25 per cent by making simple tests and repairs which involved no new purchases of expensive equipment.

Unsaturated Hydrocarbons

A most important problem today is the better utilization of motor fuels. We should appreciate that sooner or later the automobile user must face the necessity of using motor fuels that are comparatively high in unsaturated hydrocarbons. Cracking will probably become more and more general and the products of oil from oil shale also will undoubtedly be high in unsaturated hydrocarbons. The vast deposits of asphalts, heavy oils, tars, oil sands and oil shales located throughout the different parts of the United States, Canada and the South American countries will undoubtedly furnish some of our future gasoline. The possibility of the recovery of lighter oils from these sources should be investigated, for the supply is almost unlimited. The Bureau of Mines has been working on this problem for a couple of years and has demonstrated on a laboratory scale that it is possible to recover the oil from the oil sands and to even recover from the heavy asphalts light oils with a gasoline content of perhaps 20 per cent. The results of this work indicate, however, that we can expect such oils to be highly unsaturated. Investigations should be made to know which of the unsaturated hydrocarbons are harmful, whether they can be eliminated and how they can be distinguished one from another.

Lubricating Oils

Perhaps one of the most neglected branches of investigative work of the petroleum industry is the scientific study of lubrication. Most users have little idea of the proper lubricant for their special purposes. Consumers continue to use a certain lubricant for the reason that it gives a fairly satisfactory result. They are not informed, however, as to the reason some lubricants work in some cases, while they do not work in others.

A most important problem in refining engineering is the production of cylinder oils for steam and gas engines from crudes other than those of the Appalachian district. Today a large part of the cylinder stock is obtained from Appalachian crude and knowledge of how to treat other crudes is very limited. We have apparently been willing to accept this condition without studying the possibilities of the various fields.

Greater Recovery of Oil

Research problems are by no means limited to chemistry and refining, for there are real opportunities for engineering and investigative work in the production of petroleum in the fields. It has been stated that perhaps 80 per cent of the original oil is left in the sand due to the exhaustion of the gas. The manner in which gas serves as an expulsive medium was made clear by an experiment in which a steel container about 3 ft. long and 3 in. in diameter was filled with sand which was then thoroughly saturated with oil. The amount of oil introduced was known by weight and measurement. After the sand had been saturated, gas was forced into the container under a pressure of 200 lb. per sq. in. Then a valve at one end was opened and the gas allowed to escape, bringing with it perhaps 18 per cent of the oil put into the container. In other experiments the amount of oil recovered varied from 15 to 25 per cent, depending on the pressure and other conditions. After the gas had forced out 18 per cent of the oil, the container was held in a vertical position for the purpose of determining how much oil would drain out, but the capillary force exerted on the oil was so great that only a negligible quantity of oil drained from the sand. In other words, this simple experiment emphasized the fact that gas is the predominant factor in moving the oil to the well and that when the gas is gone, the production is gone. In any event it is unquestionable that large quantities of oil are left underground and whether the figure is 80 or 60 per cent, it is too large. Obviously we should start work to determine means for obtaining a greater recovery.

In certain parts of the Appalachian Fields, the practice of forcing compressed air or gas into a central well, whence it goes to adjoining wells and carries the oil with it, has caused wells to produce as much oil as they had up to the point when considered ready for abandonment. There are undoubtedly other means of effecting a greater recovery and these questions should be studied and applied before the wells are abandoned.

In connection with the prospect of there being in operation in this Country within the next few years 15,000,000 automobiles, Mr. Ambrose called attention to the fact that, although owing to the recent industrial depression, the copper industry is using 7,000,000 bbl. less gasoline per year than normal, and the ships are taking less oil from the market, nevertheless the consumption of gasoline has been greater currently than ever before. He said that the supply of shale oil is estimated conservatively at 100,000,000,000 bbl., and that Canada, Mexico and South America have extensive oil outcroppings in one form or another.

ROBERT E. WILSON

Asserting that the volatility of motor fuel, which is the property of greatest importance as regards the behavior of fuel in a manifold, is not defined by the usual distillation test, Prof. Robert E. Wilson, director of the research laboratory of applied chemistry of Massachusetts Institute of Technology, outlined the characteristics involved. His address is given substantially in full below, as it is felt that what he had to say is of such unusual importance that it should be recorded promptly. His topic was

How Can We Measure the True Volatility of Motor Fuel?

I believe that everyone here realizes, at least in a qualitative way, the importance of volatility in ease of starting, in distribution, in fuel economy and in crankcase dilution. For that reason, both the producers and the consumers have placed great emphasis upon the distillation test and upon specifications based upon that test.

It is my purpose to show that the distillation test as at present conducted, as a whole or any part thereof, is not a satisfactory measure, either of the ease of starting or of the ease of securing proper distribution by complete vaporization. Along with proper distribution comes, of course, the question of fuel economy and crankcase dilution.

I shall discuss the topic, "How can we measure the true volatility of motor fuel for the purpose for which it is to be used? and the related question, How can we draw up specifications that will insure getting what the con-

(Concluded on page 17)

Methods of Measuring Detonation in Engines

By THOMAS MIDGLEY, JR.[1] AND T. A. BOYD[2]

ANNUAL MEETING PAPER *Illustrated with* DIAGRAMS

THE various methods employed to measure detonation or fuel knock in an internal-combustion engine, such as the listening indicator, temperature and bouncing-pin, are discussed and the reasons all but the last cannot be employed to give satisfactory indications of the detonation tendencies of fuels are given. The bouncing-pin method, which is a combination of the indicator developed by the author and the apparatus designed by Dr. H. C. Dickinson at the Bureau of Standards, is illustrated and described. In this method the evolution of gas from an electrolytic cell containing sulphuric acid and distilled water measures the bouncing-pin fluctuations in a given period of time. The accuracy of this method of comparison is brought out in a table.

The qualities that a standard fuel must possess are explained and the objections to a special gasoline are pointed out. The use of a combination of a non-detonating and a detonating fuel as the standard is developed and the reasons that led to the use of hexane with diethyl selenide and isopropyl nitrite for a fuel standard are mentioned.

THE detonation that occurs in the combustion of compressed mixtures of gasoline and air has interposed an effective barrier to obtaining higher thermal efficiencies from automotive engines. Because the degree of detonation, which in conformity with what is becoming general practice is the term used in this paper to designate the fuel knock, increases with compression the compression-ratio at which engines can be run on commercial gasoline is limited, and on account of this limitation the fuel economies obtained from gasoline engines have been unnecessarily low. In spite of the importance of this factor and the attention that has been devoted to it during the last few years, no accurate method has so far been presented for measuring its intensity. The purpose of this paper is to discuss the various methods that have been used for observing or measuring detonation in engines, and to describe a new and accurate method for measuring the intensity of detonation.

Three elements are of primary importance in a universal method for measuring the intensity of detonation. First, the method should embody a means for indicating the relative intensities of different detonation waves. Second, it should comprise a means of integrating the intensities of individual waves over a period of time, and of yielding a numerical value as a result, which is accurate and can be duplicated by others using the same method. Third, a standard fuel should be used as a basis of comparison, so that the results obtained can be repeated by different observers and under different conditions.

[1] M.S.A.E.—Chief engineer, fuel research section, General Motors Research Corporation, Dayton, Ohio.

[2] Research engineer, fuel section, General Motors Research Corporation, Dayton, Ohio.

TABLE 1—METHODS OF OBSERVING DETONATION

Method	Nature of Record
Listening	Descriptive phrases, spark-advance, manifold vacuum, or compression
Indicator	Direct observation or photograph
Temperature	Degrees change in temperature
Bouncing-Pin	Volume of gas evolved per minute

In Table I are listed four different methods of measuring detonation and the type of record that is possible in each case. These methods will now be discussed in the order given. The spectroscope has been used to a considerable extent by this laboratory for studying combustion in engines. It is hoped that further development will show that this instrument can be used as a very interesting and highly accurate means of comparing one combustion with another.

LISTENING METHOD

Observations of the intensity of detonation are generally made by the listening method. The observer listens to the detonation in an engine and on the basis of what he hears decides as to its intensity. The result that is obtained cannot be very accurate, and it necessarily depends largely upon the personal equation, or the temperament of the observer. The record has been something as follows: "slight pinking," "decided detonation," "severe detonation"; and, for denoting extreme conditions, such expressions as "very violent detonation," or "it can be heard across a 10-acre lot."

This method is improved by recording the spark-advance necessary to produce some critical degree of detonation that the observer believes his hearing is trained to detect accurately, or by making use of some other factor such as intake-manifold vacuum, variable-compression engines, or water-temperature readings. All of these variations of the method depend for their value upon the keenness and accuracy with which the observer can detect slight changes in the intensity of detonation.

It has been found that an observer in a car on the road and on known hills gets results that are reasonably consistent. In the dynamometer room, however, with the attendant confusion of engine noises the results of the most careful observers are erratic and inaccurate. In fact the best trained ear in our organization is barely able to detect a difference in operation between straight gasoline and gasoline with an addition of 20 per cent of kerosene. This is an error approximately four times as great as can be detected on the road. Something better than the personal hearing of the investigator is essential if small differences in the behavior of fuels are to be studied.

INDICATOR METHOD

The use of an indicator for determining the intensity of detonation is a decided improvement over the listen-

Fig. 1—Indicator-Cards, the Top One Showing a Normal Combustion and That Underneath One in Which Detonation Occurred

ing method. We have been using such an instrument for several years. It is substantially as accurate as observation by ear on the road. In employing the indicator for this purpose it is essential that pressure-time cards be used. It is evident that fuels giving the same intensity of detonation will give indicator-cards that are alike. The accuracy with which a determination of the intensity of detonation can be made by this method depends upon the ability of the observer to compare the indicator-card of the fuel under examination with the card given by some standard fuel. Here the personal equation enters, and it is largely this factor that makes the indicator method of measuring detonation unsuitable for accurate work. In Fig. 1 (at the top) are shown indicator-cards of a normal combustion and (underneath) of a combustion in which detonation has occurred.

Temperature Method

The temperature method is based upon the measurement of the change in temperature incident to detonation. The use of the temperature factor for this purpose was suggested, we believe, by Doctor Winchester, of the Standard Oil Co. of New Jersey. It has been observed for some time that a general overheating of the engine

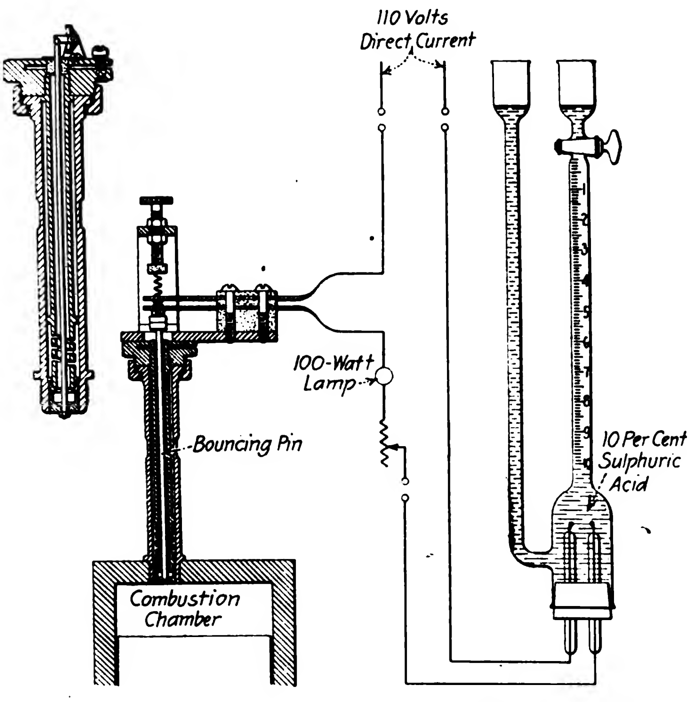


Fig. 2—At the Upper Left the Standard Pressure-Element of the Midgley Indicator Approximately One-third Its Actual Size and in the Other Portion the Knock-Indicator That Was Developed from This Pressure-Element to Embody a Bouncing-Pin

apparently occurs during detonation: the excellent work done by the Bureau of Standards established this fact beyond question.

In our use of this method a thermocouple was placed in such a position that it would be quickly affected by a change in the temperature of the internal walls of the engine. The terminals of the thermocouple were connected in a circuit in which was placed a very sensitive galvanometer. This gave a striking method for determining in a qualitative way the effects of small percentages of different materials toward inducing or suppressing detonation.

But the method was not satisfactory for making quantitative measurements of these effects. The reason for this is simple. Of the temperature, as shown by the thermocouple, 150 deg. cent. (302 deg. fahr.) is attributable to the normal operation of the engine; and, in the case of a detonating combustion, there is added to this another 50 deg. or so which is attributable to the detonation. It is evident that any minor disturbance of the normal operation of the engine will affect the temperature that is due to normal operation to such an extent as to represent a large percentage of the change in temperature that would ordinarily be due to detonation; so that, unless an impracticable amount of care be taken to hold all engine conditions constant, large errors are introduced into the reading of the temperature-change that is apparently due to detonation. For this reason the temperature method was found to be unsuitable for our work, in which quantitative data were essential.

Bouncing-Pin Method

We recently had occasion to measure the influence upon combustion of small amounts of a number of materials, some of which have weak detonation-inducing properties and others are very weak suppressors of detonation. It was essential that these slight effects be measured with sufficient accuracy to permit a proper classification of the materials. We felt that at the same time it would be highly desirable to develop for measuring and recording the intensity of detonation a system that would lend itself to the commercial testing of fuels. With these things in mind, we began the development of a method to yield results of a high degree of accuracy and give numerical values that could both be obtained rapidly and duplicated by different observers. The result of this effort has been the development of an apparatus and procedure by which can be measured the effect of the addition of as little as 2 per cent of kerosene to gasoline. This is several times as accurate as measurements can be made by the listening method under similar conditions.

An essential feature of the apparatus is a modified form of Dr. H. C. Dickinson's bouncing-pin. The small drawing in the upper left corner of Fig. 2 illustrates the standard pressure-element of the Midgley Indicator that was developed by our organization some years ago. A small piston will be observed in the end of the pressure element which is designed to come flush with the head of the combustion-chamber and transmit its motion, resulting from pressure against the resisting spring, through a connecting-rod to an oscillating mirror on the top of the pressure element.

The other portion of Fig. 2 shows the knock-detector, a part of which was a development of this pressure-element to embody a bouncing-pin. The standard piston, spring and housing of the pressure element have been used, and on top of the piston has been placed a rod or bouncing-pin that rests on the piston by gravity. In order to keep the bouncing-pin free from a small but un-

desirable deposit of gum that reduced its sensitiveness to some extent, it was found of advantage to drill a number of small holes in the outer shell of the pressure element. If the superstructure or contacting device were removed and the rod allowed to have free play, it would be observed that, during normal combustion, the rod moved up and down very slightly due to its following the movement of the piston resulting from normal pressure-changes in the cylinder. But when a detonation occurred the rod would jump upward a noticeable distance and entirely clear of the piston. In fact we have seen the bouncing-pin jump as high as 1½ in. above its normal position. As a means of measuring detonation the apparatus, even in this form, is a distinct improvement over the ear of a careful and experienced observer. But, since two successive explosions are rarely exactly alike, sufficiently accurate observations could not be made by its use alone.

To secure the desired degree of accuracy it was necessary to obtain an integration of the fluctuations of the pin over a period of time. This was accomplished by arranging contact-points held in position in an electric circuit by springs in such a way as to be closed when the bouncing-pin was thrown free of the piston. An integration of the length of time the contact-points were closed was then obtained by measuring the volume of gas evolved during a 1-min. period by an electrolytic cell placed in series with the contact-points. To the cell, which contained a 10-per cent solution of sulphuric acid in distilled water, 110 volts direct current was applied through a resistance unit, this high voltage being used to reduce polarization. Platinum electrodes were used in the cell which, as is shown in the lower right corner of Fig. 2, was designed so that the evolved gas is automatically collected in a slender graduated tube at the top where its volume can be easily noted. Since a fuel under examination was always compared with another of known properties that was run immediately before and after, no correction of the volume of gas was made for temperature or for the slight liquid pressure resulting from the design of the apparatus.

In our work, which was done on a single-cylinder engine equipped with a mixing-valve, the rapid and complete changing of the fuel entering the engine when desired was facilitated by the use of a special fuel-system. This device consists of two carbureter float-bowls, arranged to be adjustable for vertical position, and two vertical glass tubes placed side by side, each connected at its bottom to one of the float-bowls. Each of the tubes was in turn connected to a three-way stopcock from which a single fuel-line ran to the mixing-valve on the engine. This arrangement permitted rapid switching from one fuel to another maintained at exactly the same level. A means was provided for the complete draining of the part of the fuel system not in use, to permit the ready substitution of different fuels.

Table 2 is given as an illustration of the accuracy with which one fuel can be compared with another by the bouncing-pin method. The results were obtained by running mixtures of kerosene and gasoline that were prepared by another person than the operator against various blends of known composition and containing the same ingredients. The composition of the fuel under examination was, of course, unknown to the operator. The average error for the six determinations given in Table 2 is 1.75 per cent.

As previously stated, this method for measuring detonation in the combustion of compressed mixtures of fuel and air was developed primarily to compare in an accurate manner the relative strength of different anti-knock materials for the suppression of detonation. Some results which were obtained in this work are shown graphically in Fig. 3. Aniline was used as the standard for the measurements, the determinations were made on an engine of 75-lb. compression, and the same kerosene was used as fuel throughout the tests.

TABLE 2—ACCURACY OF THE BOUNCING-PIN METHOD FOR COMPARING FUELS

Actual Kerosene in the Blend, per cent	Kerosene as Determined, per cent	Error, per cent
37.50	38.75	1.25
35.00	35.75	0.75
33.00	36.00	3.00
40.00	42.75	2.75
33.30	34.50	1.20
46.60	48.20	1.60

Fuel Standards for Use in Measuring Detonation

Because the intensity of detonation as it occurs in engines varies with so many factors in addition to the character of the fuel, it is essential in measuring the detonating tendency of a fuel that it be compared directly with a standard run at the same time and under the same conditions. Such factors as spark-advance, intake-manifold vacuum, or, for that matter, the compression at which a fuel detonates, are functions of the engine as well as of the fuel.

Let us consider what constitutes an ideal standard fuel for comparative purposes. It would appear that the setting aside of a limited quantity of a special gasoline, which of necessity must have an indeterminate composition, is comparable to the use of the distance from the king's nose to his thumb as the standard for the yard, instead of a bar made of bronze. Just as the length of the yard under such a condition would not be the same on two different occasions, so the composition of the re-

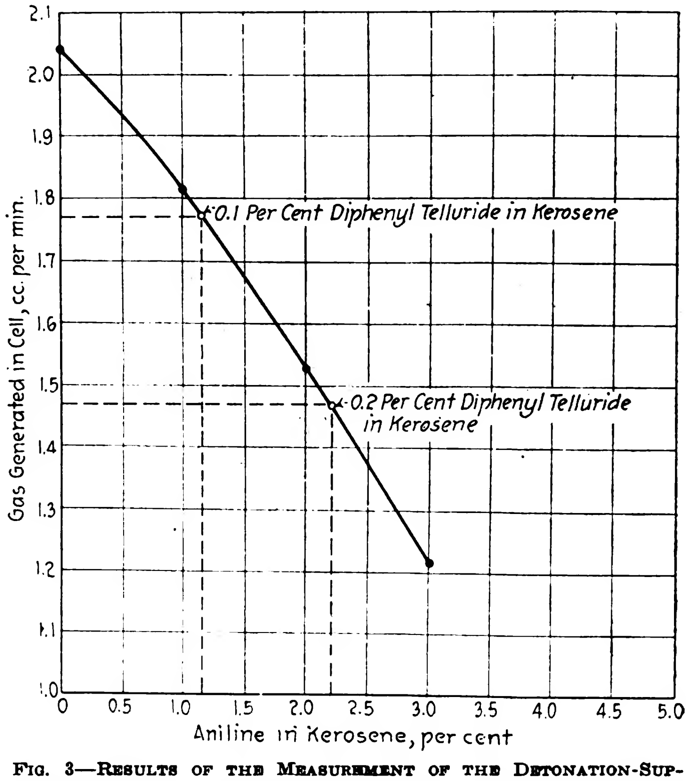


FIG. 3—RESULTS OF THE MEASUREMENT OF THE DETONATION-SUPPRESSING EFFECT OF DIPHENYL TELLURIDE BY THE BOUNCING-PIN METHOD

serve gasoline would vary from time to time unless it were sealed in an air-tight way. Furthermore, since this reserve material must be used in making tests, it must be replaced sooner or later. Any oil technologist knows that it would be practically impossible to obtain an additional supply of exactly the same material. On account of these factors a mixture of hydrocarbons of indefinite composition is unsuitable for use as a universal standard in this work. Only such fuel standards as single and pure hydrocarbons should be used. With a pure hydrocarbon as a standard fuel, additional supplies of the standard could be prepared at any time by any one having need for such a material.

For meeting these requirements it appeared that a considerable advantage would be obtained by the use of two materials, one of which would not detonate even at very high compressions, and the other give a violent detonation at ordinary compressions. The measure of the intensity of the detonation given by a fuel under examination would then be the relative percentages of these two standards required to give a blend of exactly the same detonating tendency as the fuel being measured. These materials must be such that an investigator will have little difficulty in procuring them in a pure state.

On first thought it might appear that benzene or toluene could be used as the non-detonating fuel and that sulphuric ether could be used as the detonating fuel. But blends of such materials as ether and benzene or toluene are very difficult to work with, because the intensity of detonation is extremely susceptible to slight changes in the fuel-to-air ratio. In the case of an ether-benzene fuel a rich mixture gives a very much more intense detonation than a theoretical or lean mixture. Thus a fuel of such a composition that gives no detonation with a proper mixture may detonate very violently when running on a rich mixture, all other conditions remaining the same.

This erratic operation of ether-benzene or ether-toluene blends is probably due to the fact that with rich mixtures the engine runs on the ether in preference to the benzene. The two materials are dissimilar in composition, and the ether is the more volatile ingredient. Blends of benzene and paraffin hydrocarbons exhibit the same characteristic. Thus a blend of benzene and kerosene that gives a decided detonation with a theoretical fuel-to-air ratio will show a rapid reduction in intensity of detonation as the fuel-to-air ratio is increased; so that, with such blends, unless some accurate form of instrument is used to measure the air entering the carbureter, the change of intensity of detonation with that of the mixture ratio is so great that the measurement of the detonating tendency of a fuel cannot be made with a proper degree of accuracy.

Again, if a fuel such as benzol, which is dissimilar in composition from most commercial gasolines, be blended with 5 per cent of a compound such as isopropyl nitrite, which is a material that induces detonation, and this mixture run in an engine having a compression of 75 lb. no detonation will occur. But, if this benzol-isopropyl nitrite fuel be blended with an equal volume of gasoline, which alone does not detonate in an engine of 75-lb. compression, the engine will develop a violent detonation when running on the resulting mixture of the two fuels. A similar detonation will develop, if, while running on the benzol- isopropyl nitrite fuel, a change be made to straight gasoline. But in the latter case the detonation will entirely disappear as soon as the traces of the benzol-isopropyl nitrite fuel are completely washed from the fuel-lines by the gasoline. This behavior of benzol blends is equally characteristic of other fuels, such as alcohol, that are dissimilar in composition and properties from the paraffin hydrocarbons that make up the greater percentage of our commercial gasolines.

On account of such limitations it appears that the fuels that are used for a measuring scale should be derived from either the paraffin or the naphthene series of hydrocarbons. This will insure that their characteristics when blended will not be erratic and that there will be no extreme degree of detonation during the time within which the fuels are being changed on the running engine when commercial internal-combustion engine fuels are being examined. Cyclohexane, which is the cheapest pure hydrocarbon of the naphthene series, is too expensive for such a purpose, since it costs under present conditions about $15 per gal. Only hydrocarbons of the paraffin series, therefore, appear to be available. The cost of preparing pure paraffin-hydrocarbons further limits a choice to pentane and hexane. Moreover, the low boiling-point of pentane, 97 deg. fahr., makes it unsuitable for use as a standard fuel. It appears, therefore, that hexane is the only material that is suitable for use as the basis of the system of standard fuels.

Hexane can be prepared in considerable purity by repeated fractionation of casing-head gasoline from the Pennsylvania field. It boils above 150 deg. fahr., which is considerably higher than the initial boiling-point of commercial gasolines, so that it can be used in hot weather without boiling in the fuel-lines. Because it is a member of the paraffin series of hydrocarbons its structure is very similar to that of the principal constituents of commercial motor fuels. It therefore appears to meet most nearly the rigid requirements for the basis of the standard fuels for use in the measurement of detonation as it occurs in internal-combustion engines.

But hexane does not have a sufficient tendency to detonate to be used alone for the upper end of the scale of standard fuels, nor is it sufficiently free from tendency toward detonation to be used as the fuel for the lower end of the scale. This difficulty may be overcome by taking hexane as the basis of the fuels at both extremes of the scale, and adding to one portion a detonation-inducing material to give the fuel greater tendency to detonate, and to another portion an anti-detonating material to make the fuel of lesser tendency to detonate. The standard scale would then lie between these two fuels, and the point on the scale representing the tendency of a fuel, X, to detonate would be designated by the relative percentages of the two standards required to give a fuel of the same characteristics as X from the standpoint of detonation.

A survey of the known materials that may be added to hexane for producing the above-mentioned effects indicates that isopropyl nitrite is most suitable for the detonation-inducing material, and that diethyl selenide is best suited for the detonation-suppressing material. Of the considerable number of other compounds that might appear suitable for use in this connection, none can, for one reason or another, be used for the purpose. For example, aniline cannot be used in a solution in which isopropyl nitrite is present, because of a reaction that takes place between the two materials. Isopropyl nitrite is very effective for inducing detonation, and diethyl selenide is about 10 times as effective as aniline for suppressing detonation. Both of these materials can be easily prepared, they are reasonably cheap, and both have the advantage of ready solubility in petroleum oils.

A considerable amount of work has been done in the measurement of the detonating tendencies of fuels by

the bouncing-pin method, using a 5-per cent solution of isopropyl nitrite in hexane and a ½-per cent solution of diethyl selenide in hexane, respectively, as the upper and lower ends of the standard scale. Fig. 4 shows graphically some results that were obtained. The amount of work that has been done so far in which such a fuel system was used as a standard has not been sufficient to establish the unquestionable superiority of this particular system of fuels for use under all conditions in the accurate measurement of detonation in engines. However, in the use that has been made of these standards, very good results have been obtained; and it seems certain that the ultimate standard fuels will consist of some form of detonation-inducing and anti-detonating materials dissolved in hexane.

Conclusion

An accurate observation of and a universal means for recording the intensity of detonation as it occurs in combustion can be obtained by making use of a system comprising

(1) An adaptation of Doctor Dickinson's bouncing-pin
(2) A means of obtaining an integration of the fluctuations of the pin over a definite period of time
(3) A system of standard fuels based upon a member of the paraffin series, preferably hexane, one portion blended with a detonation-inducing material and another portion blended with a detonation-suppressing material

Such a system when used by the ordinary observer will yield results that can be duplicated with accuracy from day to day, and when used by different observers will give results that are comparable.

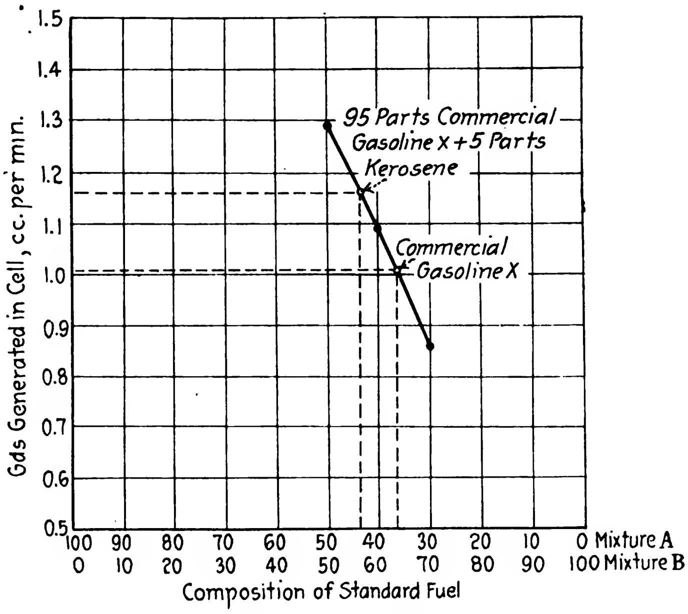


Fig. 4—Results of a Comparison by the Bouncing-Pin Method of Two Fuels with a System of Standard Fuels
Mixture A Was Composed of 95 Parts of Hexane and 5 Parts of Isopropyl Nitrite and Mixture B Was Composed of 99½ Parts of Hexane and ½ Part of Diethyl Selenide

DECEMBER COUNCIL MEETING

The last session of the Council was held in Chicago on Dec. 5, during the week of the annual meeting of the American Petroleum Institute, in connection with which preliminary conferences were held by the Research Committee and the officers of the Society. The following members of the Council were present: President Beecroft, First Vice-President Horning, Second Vice-Presidents Bachman, Crane, Johnston and Menges, Past-President Vincent and Councilors Davis and Brush; and in addition, O. C. Berry, V. E. Clark, H. C. Dickinson, F. E. Watts, O. W. Young, and Chairman Pfeiffer and Secretary Milton of the Mid-West Section of the Society.

At the President's Dinner in the evening at the Chicago Athletic Association there were present also Herbert Chase, A. W. Ambrose and N. A. C. Smith of the Bureau of Mines, L. C. Freeman, R. O. Hendrickson, W. S. James, E. S. Jordan, Thomas Midgley, Jr., Dent Parrett, Prof. Daniel Roesch, of Armour Institute of Technology, Prof. R. E. Wilson, of Massachusetts Institute of Technology, O. B. Zimmerman, P. S. Tice and B. B. Ayers.

Fifty-four applications for individual membership and 19 for student enrollment were approved, as well as the following transfers in grade of membership: Junior to Member, T. J. Gorman; Associate to Member, Eustace B. Moore, J. D. Lannon; Foreign Member to Member, Edward C. Lange.

One hundred and twenty-four applications for membership were received during October and November as compared with 200 for the same two months of 1920. On Dec. 3 there were 5246 names on the rolls of the Society, including affiliate member representatives and enrolled students, as compared with 5230 on the same day of 1920, the slight difference being due to the fact that 662 ceased during the period to be members principally on account of non-payment of dues.

The balance sheet as of Nov. 30 showed a deficit of $1807.53 for the first 2 months of the current fiscal year. This deficit is less than that authorized by the budget that was approved by the Council in September, the decision having been that the Society should proceed this year in an active manner doing practically all of the work it had done theretofore and in addition maintaining the Research Department that was established recently; although such procedure might involve greater expenditure than income of money during this year. The income during October and November amounted to $35,525.84. The surplus funds of the Society amount to $136,817.94.

A comprehensive report was received from the Meetings Committee with regard to meetings of the Society to be held early in 1922.

The following appointments on Sectional Committees of the American Engineering Standards Committee were made:

Insulated Wires and Cables	F. W. Andrew
Aeronautic Safety Code	G. J. Mead
Ball Bearings	L. A. Cummings

A report was received from the Standards Department in the matter of the Standards Committee Division reports that it was expected would be submitted for consideration at the 1922 Annual Meeting of the Society.

Past-President Alden was designated as chairman of a committee of five that is to be organized to represent the Society in cooperative work on highway matters with Government, engineering and trade organizations. It is contemplated that the committee will also do some independent work, probably in conjunction with the Research Committee of the Society. The major consideration is the relation between the automotive vehicle and the road, this involving of course the relative cost of highway and of vehicle maintenance. It is the intention of the Council, which appreciates fully the many ramifications involved in the studies required, that the Committee shall proceed in as constructive a manner as possible on all of these matters that are submitted to it.

The next meeting of the Council will be held in New York City on Jan. 9.

Manufacture and Application of Automobile Varnishes and Paints

By L. VALENTINE PULSIFER[1] ANNUAL MEETING PAPER

DIVIDING the ability of an automobile finish to remain new into the elements of proper quality of the materials, engineering of application systems, methods of application and care of the finish, the author states that the responsibility for them rests jointly upon the manufacturer of the varnishes and paints, the builder of the automobile and the owner of the finished product. Five basic materials that are necessary in automobile painting are specified and discussed.

Engineering systems of application and the actual methods of application are treated in some detail, inclusive of drying, and of surfacing or rubbing. The care of the finish is important and the precautions necessary in this regard are outlined. The paper deals with the application and not the manufacture of the different varnishes and paints that are mentioned.

THIS subject is far too broad to be covered in detail in one paper. I will therefore lay greatest stress on the problems met in the proper application of automobile varnishes and paints, rather than on those involved in their manufacture, believing that it is the problem of application that interests automotive engineers chiefly. The importance of the finish of an automobile was never greater than it is to-day, for the degree of mechanical excellence already reached leaves, as the most obvious next step in development, a still further improvement in the appearance and durability of the finish. This is desirable, first, from the viewpoint of sales appeal and, second, for the strength that satisfied ownership gives to the manufacturer whose car not only continues to be good mechanically but, in addition, continues to be new in appearance.

The ability of an automobile finish to remain new is the product of four elements, the slighting of any one of which is bound to be fatal to satisfactory results. These four elements are the proper quality of the materials, engineering of the system, methods of application and care of the finish of the car. The responsibility for these four essential elements is divided among three different interested parties: the maker of the varnishes and paints, the builder of the automobile and the owner of the finished product. Unless all three do their share, the production and retention of a finish that remains new are utterly impossible. The setting forth of these four elements provides a natural division of the subject-matter of this paper into materials, systems, methods and care, to be considered in the order named.

MATERIALS

Under the subject of the materials that go into the building of the finish of an automobile, I will cover certain points in the manufacture of varnish that will help in the understanding of the problems met in its application. There are, I presume, about 500 manufacturers of varnishes and paints in the United States. Not more than 10 per cent of these make any attempt to manufacture materials especially adapted for use in large automobile or body plants, and not much over 1 per cent exert their major efforts along these lines. "Varnish" and "paint" may be made by a man with a minimum of plant, of capital, of organization and of stocks of material. On the other hand, they may be manufactured by a company with millions invested in plants, equipment and materials both raw and finished, that has extensive laboratories, a large staff of scientific and technical experts and years of experience in a highly specialized branch of the industry.

Paint covers a range from home-made whitewash to a highly technical product such as the japan color used on an automobile. Varnish embraces everything from wall-size to wearing-body. The former is a simple solution of hardened resin in benzine and the latter is the acme of the scientific varnish-maker's art. I use the word "art" advisedly, for it literally requires art in addition to scientific skill and unlimited resources to produce in its most highly developed form the final flowing coat of varnish that completes the finish of an automobile. The varnishes that are used in automobile painting are all oleo-resinous varnishes and the various pigmented materials that are used to bring up the surface and produce the desired color, ranging from the highly elastic and impervious primer to the very inelastic and somewhat porous japan color, can be classed as varnish paints. Thus, in a broad sense, varnish forms the basic material of each coat that goes to make up the completed finish.

Oleo-resinous varnishes contain four classes of material; gum resins, fixed vegetable drying-oils, volatile vegetable or mineral oils and metallic driers. The gum resin gives to the varnish hardness and brilliancy; the fixed vegetable oil imparts elasticity and durability; the metallic driers aid the film to absorb oxygen during the drying period; and the volatile oils or thinners reduce the varnish to a workable viscosity. To understand the character of a dried film of varnish, the volatile oils, or thinners, having evaporated, can be disregarded. The driers, which have completed their function in assisting the films to absorb oxygen and become hard, can be disregarded also. The dried varnish can be considered as an alloy of gum resin and fixed vegetable oil, and its character and performance predicted by the relative proportions of these two ingredients. Varnishes that contain less oil than gum are called "short-oil" varnishes, while those containing more oil than gum are termed "long-oil" varnishes. Most rubbing varnishes fall in the short-oil category, while all finishing varnishes are long-oil varnishes.

The quickest rubbing-varnishes sometimes have as much as two parts of gum to one of oil. Three and 4-day rubbings are on the border-line between short and long-oil varnishes, some of the 4-day rubbings containing slightly more oil than gum. Finishing-varnishes range from quick gear-varnishes, containing about two parts of oil to one of gum, up to body varnishes running as high as four or five parts of oil to one of gum. Of course,

[1] Chief chemist, Valentine & Co., New York City.

the character of the individual materials and the processes by which they are combined, as well as the proportions in which they are "alloyed," help to determine the quality of the finished varnish. Considering materials of similar quality, the short-oil varnishes are quick-setting, fast and hard-drying, inelastic and, if exposed to the weather or even to extreme changes of temperature without the protection of a long-oil finishing varnish, will soon crack and perish. On the other hand, the long-oil varnishes work freely, flow smoothly, set slowly, dry and harden gradually and possess a high degree of elasticity. The higher the percentage of oil in their composition, the greater is their degree of elasticity and durability. They do not, of course, dry hard enough or fast enough for use in the rubbing coats, but they possess the durability necessary to afford the final protection for the whole paint structure.

The japan drier or grinding japan used in the japan colors and some of the other automobile undercoats, is really either a long or a short-oil varnish in which is incorporated a very high percentage of metallic drier. This causes the film to dry with much greater rapidity than would be the case with a normal varnish of the same gum-oil ratio and, at the same time, reduces the elasticity very greatly.

In the production of high-grade varnishes extreme care is necessary in the selection and testing of all the raw materials; in the aging, refining, bleaching and heat-treating of the oils and in the melting of the gums and their combination with the oils. Careful testing of the base, or primary, varnishes, their proper storage and selection for the blending or mixing process in the formation of the secondary or finished varnishes and, finally, the rigid check-testing against standards of each tank of the finished product, form an essential part in the production of reliable material. A full description of each step and process, from the time of arrival of the raw material at the plant until it goes out a year or so later as the finished article, would be too lengthy, and I will therefore proceed with the description of the various types of material used in building up the automobile finish from the foundation to the final coat.

Basic Materials

Five basic materials are used in automobile painting; those for priming, surfacing, coloring, rubbing and finishing. Each of these materials performs a distinct and different function and all are necessary links in the completed chain.

The primer forms the bond between the surface to be painted and the subsequent coats of material. It is the foundation of the whole structure. It must be of suitable nature to perform its duties properly and be applied over a surface properly prepared to receive it. There is no failure worse than that due to an improper primer, a primer that is improperly applied or one applied on a surface not in condition to receive it.

The surfacing materials are used for the purpose of building up a smooth surface on which to apply the color, rubbing and finishing-coats. There are two types: those surfaced by sandpapering and those surfaced by rubbing-down with block pumice or rubbing-stone and water. These latter are tougher and more dense and, although they require more time and labor, naturally give the most complete and most durable results.

Coloring materials include the so-called ground colors, japan colors, flat colors or body colors. They form a dense opaque ground on which to apply the subsequent rubbing-coats. They are extremely rapid in drying, show no gloss and should be semi-porous in nature to permit the varnish of the first rubbing-coat to penetrate to a certain extent. They are the least elastic of all the materials and are composed of pigments of the desired color carefully ground in grinding japan.

Rubbing materials comprise all types of clear and colored rubbing-varnish and the preponderance of gum in their make-up gives them a hardness that permits of their being rubbed to a smooth surface. This is done preferably with pumice-stone flour, a felt pad and water. They range from materials that air-dry to rub overnight to those that take 4 days to reach the requisite hardness for proper rubbing-down. The colored rubbing-varnishes are either factory-made by grinding the proper dry pigment into the varnish, or shop-made by the careful addition of japan color to the clear rubbing-varnish. The type of rubbing-varnish selected should be gaged by the character of the work to be turned out, the slower and more durable grades being indicated for the finer types of finish.

The finishing-varnishes used in automobile work represent the most highly developed type of oleo-resinous varnish used for any purpose. They must work and flow faultlessly, dry within a reasonable time, present a surface of mirrorlike smoothness and possess adequate toughness and elasticity to insure long life. Hardening to a final thickness of less than 0.001 in., they must protect the whole paint and varnish structure against all the elements and only too often against the abuse or neglect of a careless or ignorant owner. They are long-oil varnishes in the truest sense, and range in grade from those suitable for quick repair-work, drying to handle overnight, to the best body varnishes that require several days under normal air-drying conditions to harden sufficiently for use.

Body varnishes should be chosen for their paleness of color, freedom and safety of working, speed and perfection of flowing, time of drying and hardening in relation to durability, fullness of body and brilliancy of finish. A different type of finishing-varnish should be chosen for the hood, fenders and wheels from that used on the body, for one is needed that is more resistant to the action of mud, water, oil, grease and soap, than is required on the body. A varnish of this type does not possess the freedom of working and flowing of the finest grades of body varnish but, fortunately, the surfaces to be finished are much smaller and working qualities can be sacrificed safely to obtain greater body, toughness and resistance.

The finishing-varnish is to the paint beneath what the armorplate belt is to the vitals of the battleship and the life of the whole structure depends on its quality. It must be of the best and, even then, it cannot perform its duties successfully if placed over poor undercoats improperly applied, or over a system of painting improperly engineered.

Engineering Systems of Application

This consideration of the five basic materials appearing in a complete system of automobile painting brings us to the matter of their proper combination into the finished structure. The laying-out of an automobile painting system is an engineering problem of no less magnitude than the design of a steel bridge and, in many ways, is more complex. The various materials perform different functions exactly as do the foundations, anchorages, columns, girders and trusses of a bridge. They must bear proper relationship to each other and to the completed structure as do the various bridge members;

each must be designed and proportioned properly in relation to all the others to produce a perfect result.

The simplest possible system would consist of one coat each of primer, surfacer, color, color varnish and finishing varnish. Over a perfectly smooth, flat, metal surface, such a system would give good results as to both appearance and durability if the materials used were of the best. Under the actual conditions of automobile painting, at least double the number of coats noted above usually will be found necessary to produce a finish of good appearance and durability. In this connection it should be noted that it is just as bad practice to pile on unnecessary coats as it is to leave off materials that are necessary to the system. Just enough coats should be specified to produce the desired degree of fullness of finish. Proper shop facilities must be provided, a full time schedule allotted and an adequate degree of skill afforded in the personnel of the painting department to insure intelligent application. It is well to remember that the paint-shop and the trim-shop schedules should be interlocked wherever possible to provide *extra* days for the drying and hardening of rubbing-coats and, in this manner, added insurance of satisfactory results obtained without sacrifice of time.

In laying out the system for a given job it cannot be over-emphasized that the five basic materials must be chosen not only for their individual merit but for their ability to pull together. To obtain the proper correlation of the various coats the elasticity of the succeeding materials should be gradually *decreased* from the primer to the flat color and then gradually *increased* up to the finishing-varnish. This result is obtained by using an elastic primer. Next, a coat intermediate in elasticity between the primer and the surfacer is used; it is the so-called half-and-half or elastic roughstuff. Then the surfacer itself, possessing less elasticity, is applied, and next the flat color possessing practically no elasticity. This should be followed by gradually increasing the elasticity of the rubbing-coats produced by making each succeeding coat lower in japan color or pigment content and, finally, capping the whole with a finishing-varnish possessing the greatest degree of elasticity possible.

Methods of Application

The four methods of applying the various materials to the automobile surfaces are those of dipping, spraying, flow-coating and brushing. Dipping is used principally for the application of black baking-japans on hoods, fenders, splash-guards and small metal parts. When used in connection with endless-chain baking-equipment and a high-grade of black japan, this method affords a combination of low operating cost with a durability of finish that cannot be equalled for quantity-production work; it is used with success even on small open bodies when a black baked-finish is standard.

The now highly developed air-brush or air-gun affords perhaps the best method yet discovered for the application of the primer, surfacer and flat-color coats. It does away with troublesome brush-marks in the surfacer and flat-color coats and, in the hands of a skilled operator, gives a uniformity of thickness unexcelled by the most careful brushing. Care should be exercised in spraying to use the materials at just the proper degree of viscosity, and the operator should be cautioned especially against applying too thick a coat. This method effects a saving in time and labor that more than offsets the use of somewhat more material than in the case of brush application.

Flow-coating is a method of applying rubbing and finishing-varnish that was first tried on a very small car and now is in use in a number of large plants producing cars of the higher grades. In flow-coating, the body to be coated is mounted over a trough-like table and the varnish is applied through a flattened nozzle attached to a hose. This hose in turn is connected to a circulating pump and small reservoir of varnish. The varnish is flowed on the panels in great excess, drips off the panels into the troughs and is led back through a strainer to the reservoir from which it was originally pumped. Flow-coating possesses both good and bad points. From the viewpoint of speed of production, cheapness of operation and cleanness of finish it has great merit, but from the standpoint of the fullness and durability of the finish its use is not so successful. In the case of the rubbing-coats the tendency of short-oil varnishes to "silk," to show vertical satinlike streaks when flowed-on, more than offsets the gain made by the elimination of brushmarks. I have seen cases where this vertical silk in the flowed-on color-varnish coats was so pronounced that it could not be rubbed out without danger of cutting through to the coat underneath and, of course, this vertical silk showed through in the finishing-varnish. Also, the fact that rubbing-varnishes set or stiffen-up much more rapidly than long-oil varnishes tends to cause too wide a variation in the thickness of the film between the top and bottom of a panel. Rubbing-varnish, when flow-coated, tends to form too heavy a "fat edge," especially around door panels, to harden through properly, and this fat edge, containing semi-hardened rubbing-varnish, often wrinkles when it is softened by the turpentine of the finishing-varnish. If flow-coating is to be used for the rubbing-coats, the objectionable features that have been mentioned can be minimized by using the freest-flowing rubbing-varnishes obtainable, and their use as color varnishes in fairly thin body. For fine work the brushing of the rubbing-coats is the best practice.

The flow-coating of finishing-varnish results in a thinner residual film than is produced by the proper brushing-on of the same varnish, and this reduces both the fullness and the durability of the finish. The reason for this is apparent when it is remembered that in brushing a large panel a finisher will work over it fully 5 min. and, as something like half the turpentine content of the varnish evaporates in the first 5 min. after it is spread, it can be seen that the finisher, on his last time over the panel, is working and keeping in place a varnish of far greater viscosity than he originally applied. The average high-grade body-varnish contains about 65 per cent by weight of non-volatile material, and it will be seen that, when the finisher is through brushing it, the non-volatile content has run up to over 80 per cent. On the other hand, in the case of the flow-coat the body is being flushed with a great excess of varnish of the original viscosity until it leaves the hands of the operator, and the resulting film is consequently considerably thinner. On samples of varnish examined after a day's run in a flow-coat machine the increase in non-volatile content was only 2 or 3 per cent.

The fullness of a flow-coated finishing-varnish can be improved by extreme care in the application and rubbing of the rubbing-coats, but this solution is hardly possible where piecework prevails, for by extreme care is meant *extreme care!* The sacrifice of durability by flow-coating the finishing coat may possibly equal 20 per cent and this, unfortunately, cannot be obviated by the use of finishing-varnishes of much greater viscosity or higher non-volatile content, on account of flowing

difficulties around door-handles, wind-shield supports and moldings. Close cooperation between the automobile engineer, the foreman of the paint-shop and the chemical engineer of the varnish manufacturer will no doubt overcome in time the present objections to flow-coating on high-grade work. A so-called solution has been reached in some cases by the substitution of a finishing-varnish much shorter in oil, which, by virtue of its greater gum-content, shows a filling-up quality not possessed by a varnish long enough in oil to furnish the proper degree of durability. Such a solution will result in the sacrifice of 50 to 75 per cent of the ultimate durability of the finish, and would not be possible if proper cooperation existed between those responsible for the production of the finish.

The time-honored method of brushing, in applying all paint and varnish coats, is now restricted to use on the last two basic materials of the system, the rubbing and the finishing-coats. For these two materials application by a skilful brush-hand still represents the best practice and is in almost universal use where fine finishing is done.

Drying and Surfacing

Two other subjects come under methods of application; drying and surfacing or rubbing. The former is divided into air-drying, forced drying and baking. If time and space were no object, there would be no choice in final results between proper air-drying and proper forced-drying; but both time and space are highly important in modern quantity-production and forced drying reigns in all uptodate plants. In general, the degree of heat used should decrease with each succeeding type of material, the air used should have the requisite moisture-content to give the proper drying-rate, the heat should be applied gradually and adequate time should be allowed for the job to cool before beginning the next operation.

It is not the function of this paper to give details as to temperatures or hours required for each type of material. The rules given are general in their application. Forced drying is of little value in the final hardening of a long-oil body-varnish; the use of a temperature of much more than 85 or 90 deg. fahr. in the drying of such material merely results in a finish of thinner appearance. The main requirement in the proper drying and hardening of the best grades of finishing-varnish is a maintained temperature of at least 75 deg. fahr., without excessive humidity, and with an adequate supply of oxygen introduced by suitable ventilation. In the modern finishing-room and "dark-room" the use of an adequate air-conditioning equipment is highly desirable, especially for the assurance it gives of proper drying and hardening during humid or muggy weather. By adequate air-conditioning is meant the facility for reducing humidity as well as increasing it.

What has been said applies to the air-drying of all paint and varnish coats where air-drying is used. When forced drying is used, too much heat, heat too rapidly applied or too little moisture-content for the amount of heat used will result in "case-hardening" or surface-drying rather than proper hardening throughout. This causes a sunken-in appearance of the finish and frequently results in a premature breakdown of the whole paint structure under exposure. Like many other operations, it is erring on the safe side to go too slowly with forced drying rather than too fast.

The term "baking," when properly applied, refers to temperature-ranges above 300 deg. fahr. and to materials that harden more by heat than by oxidation. True baking is applied exclusively to blacks and, except in the case of a few small cars of very large production, is used only on hoods, fenders and the like. True baking materials cannot be used for air-drying, no matter how long a time schedule is allowable, for they would never air-dry to proper hardness.

The operations that apply to the surfacing and rubbing materials have much to do with both the appearance and the durability of the finish; more than they are sometimes given credit for. Surfaces are either sandpapered or rubbed with block rubbing-stone and water as previously described. Sanding surfaces should never be rubbed along with the use of water, because they are too porous, and the roughstuff type must be rubbed with rubbing-stone and water because they are too tough to be sandpapered.

The three methods in use for the rubbing-coats are those of dry-oil sanding, wet-oil sanding, and rubbing down with pumice-stone flour, a felt pad and water. Of these three, the last is the best practice when both appearance and durability are prime considerations. The dry-oil sanding, using sandpaper dipped in linseed oil and allowed to dry, sacrifices something in the smoothness of the finish, although it probably does not impair the durability. The wet-oil sanding, using sandpaper dipped in a mixture of linseed oil and gasoline, undoubtedly saves time and labor, but it causes a softening of the rubbing-varnish that is detrimental to the durability of the finish; this is especially true when the first coat or two of the color-varnish is wet-oil sanded and the final coat is water-rubbed.

As the rubbing with water tends to harden the coat instead of softening it, as is the case with the wet-oil sanding, this places the hardest of the rubbing-coats on top and results without question in the speeding-up of the breakdown of the finish. The use of the wet-oil sanding cannot be considered good engineering practice where the quality of the finish is the first consideration. The use of the dry-oil sanding, a substitute for the old mossing-off with curled hair, is allowable on the first coat at least of the color-varnish, although a water-rub on all coats is undoubtedly preferable where the sheer quality of the results is to be considered. This rather sketchy treatment of the methods of application is intended to be suggestive rather than informative, and yet to point out some of the possible pitfalls that high-speed production methods sometimes introduce.

Care of the Finish

This brings us to the fourth and final element in the production and retention of a satisfactory automobile finish. We will take it for granted that the varnish manufacturer has made and the automobile builder chosen the finest materials it is possible to produce, and that these materials have been applied pursuant to a scientifically sound system according to the best methods. It then rests with the car owner to do his share by treating the finish of his automobile as carefully as he would any other fine thing that he wishes to preserve.

Many car owners fail to realize that in their hands lies the matter of their cars looking as well months after they have been purchased as they did when they left the factory's finishing-room. If the owner allows caked mud to remain on the car, it may leave a spot that cannot be removed. A careful washing with clean cold water before the mud dries will avoid such spotting. Varnish will not withstand the dusting or rubbing of mud off of it, nor will its high luster survive if dust, grit and mud are driven into its surface by the water blast of a high-

pressure hose. Improper soaps, or good soaps improperly used, are a source of premature destruction of the finish, and it is dangerous to use body-polishes or so-called dry-washes and cleaners. These result in the scratching, abrading and sometimes softening of the finishing-varnish, all of which tends to shorten its life. Polishes containing wax cause trouble in the drying and decrease the durability of the new coats when a car is refinished. Many owners appear to assume that a varnish can last forever and, consequently, fail to have their cars re-varnished before the deterioration of the finish has gone so far that the undercoats are cracked and checked and a complete repainting of the car is necessary to give the car a good appearance.

All the above-mentioned difficulties can be avoided or at least minimized by instructing the owner, in the first place, what the finish of the car is and, in the second place, how to care for it properly in both upkeep and renewal. A good-looking car on the road is the product of the combined efforts of the varnish maker, the automobile builder and the car owner; and a credit and a lasting satisfaction to all three.

ENGINEERS AS MANAGERS

In an address before the Founder Societies, Philip Cabot condemned the engineer as a manager, stating that the discipline of his professional career has curbed his enthusiasm and caused him to add 15 to 25 per cent as a factor of safety to what is indicated by his painstaking calculations. Mr. Cabot said in part

> Many reasons are assigned for the collapse of the railroads, and as in the case of all other human beings, there is doubtless no one cause. But it is very striking to note the change in type of the men who now lead the great railroad systems as compared with the men who led them when they were successful. In the earlier days our great railroad leaders were primarily traffic men; men whose vision naturally focussed upon the market, who saw the thing to be done and found some way to do it. Now the leaders of our great railroad systems are all operating men; in other words, essentially men of engineering training and the scientific type.
>
> It is doubtless true that whatever the ability of these men might have been, success has been made impossible by the systems of regulation under which they have been placed. Holding the ignominious position of responsibility without power, it is no wonder if they have failed in successful leadership. But it is undeniable that they have failed conspicuously. The huge army that these men command, far from being inspired by the enthusiasm and loyalty that are essential to success, is admittedly upon the verge of mutiny.
>
> In all great operations, new or old, the leading dominating spirit must be that of the idealist, the promoter, the great salesman, rather than the student or man of science. Such an attitude of mind is very difficult for the typical engineer on account of his temperament and his training. His natural position is that of the hand that executes rather than the mind that conceives. Leadership is not native to him, his enthusiasms have been put under stern control; locked up so that they cannot warp his judgment, they cannot easily be released to inspire others. In fact, they are often atrophied.
>
> I do not say, nor do I believe, that it is impossible for an engineer to be a great leader and manager of industry. All that I can maintain is that his natural handicap is increased by our present methods of training to such an extent as to make him an unpromising candidate for promotion to such positions, and I say this with full knowledge of the fact that his selection to fill them has become increasingly common of late years especially in public-service corporations.
>
> Stockholders are in practice a flock of sheep incapable of concerted intelligent action but eager to follow any leader, so that the task of selecting corporation managements falls upon the banker, or financial godfather of the enterprise. Such men, cautious by nature, and made doubly so by experience, yearn for a sure thing and welcome the engineer with his mathematical accuracy. Your engineer at least will not exceed his estimates, will tell in advance what he will do and do it, while your most visionary promoter must forever be watched and guided. With an engineer at the wheel the company will run itself and the banker-director can sleep in peace. But there is apt to be a rude awakening when he discovers that the business has gradually evaporated, wages have shown a disconcerting tendency to eat up profits and customers are becoming surly.
>
> In this case, as in all others, the search for the sure thing fails; temporary peace is purchased at the cost of the ultimate failure and the practice must be abandoned. The bankers must select men of enthusiasm, courage and vision and put over them boards of directors who are capable and willing to direct. Your dreamer without direction will wreck you faster and more certainly than your man of science. But with adequate direction and control he is your safest man; and if our engineers are to occupy such positions with success their education and training must be profoundly modified.

There is enough probable truth in Mr. Cabot's statements to make them misleading. What he deplores is the passing of the stage in the development of the Nation when conditions favored the success of the promoter type of men. There is no longer so much opportunity for the promoter who lacks technical knowledge and ability. Any large success requires both vision and sane direction based on technical knowledge. The quality of vision is not restricted to any one type of man. Success is as likely to come under the management of a leader who has technical ability upon which to base sound judgments, and the courage to proceed, as under the management of men of the type for which Mr. Cabot pleads so interestingly.

CHICAGO FUEL MEETING

(*Concluded from page 6*)

sumer demands and yet place a minimum of restrictions upon the refiner or any one else who can add a drop to our bucket of motor fuel?

I want to say a few words with regard to specifications. Specifications have often been held up as one of the greatest obstacles to progress; indeed it has been true too often that specifications have merely taken the place of age-long prejudice and time-honored practice, to prevent *any* change, however desirable it might be to both consumer and producer.

If we analyze these cases, however, it becomes evident that the real source of difficulty is that we have not specified those properties that we really needed, but instead have tried to fix some non-essential property or some superficial indication of the desired property that happened to be more easily measured.

On the other hand, if we have specifications and tests that measure actually what we need and give them a reasonable measure of flexibility so that they may change with changing conditions, a specification becomes an *aid* to progress.

It is therefore extremely important to get satisfactory methods of tests. The volatility of motor fuel affects two entirely different things: First, the ease of starting, which is mainly controlled by the *lower* end of the distillation curve; and, second, the ease of distribution or the possibility of complete vaporization, which also determines economy and dilution. These are two separate properties and we need two separate tests for them, but *no more*.

Take first the question of what constitutes a measure of the relative ease of complete vaporization of two fuels as affecting distribution, etc. We can get some sort of an approximation to perfect distribution, even with liquid drops still present, by a proper design of manifold, but the only thing that will really distribute properly is a completely vaporized fuel. The most successful attempts to accomplish that have resulted in heating the airstream to a very considerable extent.

A measure of the comparative value of fuels for this purpose would therefore be the temperature to which the airstream would have to be heated to make possible complete vaporization. The question at once arises, Why is this point not the end-point of the fuel? or Why does it not bear some direct relation to the end-point?

There are two entirely different ways in which vaporization can take place, one of which occurs in a distillation flask and the other under the conditions that prevail in the manifold. In the one case, consider that we have a distillation flask nearly full of a fuel, and are continually distilling it off. Suppose that the fuel consists of very volatile, less volatile and still less volatile fractions, which I will designate as *A*, *B* and *C*. *A* is the first thing that comes off. It fills the vapor space, and more *A* comes off and keeps shoving it out of the way. Then *B* begins to come off, also forcing *A* out of the flask, and before half of *B* is gone, *A* will be almost completely scrubbed out of the flask. Similarly, before half of *C* is gone, *B* will be practically completely scrubbed out of the flask. The end-point we get, that is, the temperature necessary to vaporize the last drop of the fuel, will depend almost wholly upon the least volatile materials in the fuel, since the composition of the boiling liquid depends upon that of the vapor in contact with it.

There is, however, another way we can carry out this vaporization. We can have a tall gas-holder filled with air, with a fan to get circulation, and just a little pot of motor fuel in the bottom. We can start to vaporize *A*, *B* and *C* into this space, and keep stirring the air around to have equilibrium in there. We are now vaporizing this liquid into a space that *already contains* all that has thus far been vaporized. Some *A* is therefore continually redissolving in the liquid to make up for that which is evaporating and when we get down to the last drop it does not consist merely of *C*, the last volatile portion, but there is a considerable amount of *B* and some of *A*

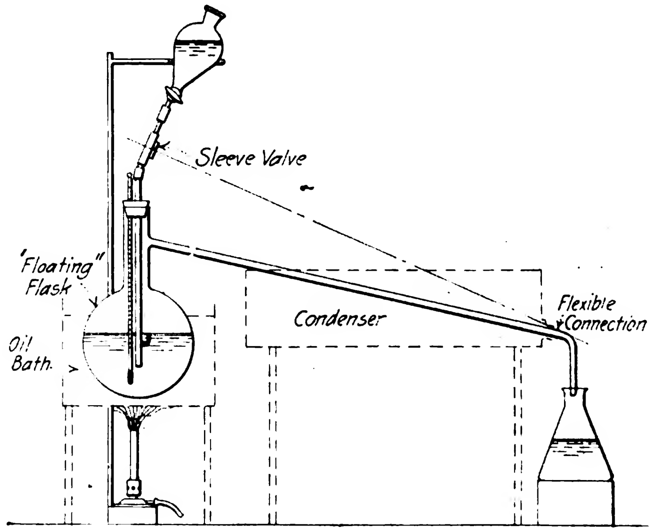


Fig. 1—Apparatus for Preparation of Equilibrium Solution Arranged for Automatic Regulation

still present. The composition of the last drop is therefore a sort of integration of the whole distillation-curve from the standpoint of completeness of vaporization into an airstream. It is much more volatile than what we got in the ordinary distillation test because it contains a considerable portion of these lighter ends. It does, however, contain a greater proportion of the heavier ends, its average boiling-point corresponding roughly to the 85-per cent point of the original fuel.

Now this last method of evaporation is essentially that which takes place in the manifold of an engine, because the last drop of the fuel is evaporating into an airstream already containing the lighter constituents. A method that we have developed for securing a sample of this equilibrium mixture corresponding to the last of the fuel to evaporate in a manifold has been described in detail[1]; so I will merely summarize the operation, which is carried out in a flask such as that shown in Fig. 1. The upper reservoir is kept full and the flask filled half-full with the fuel to be tested. The temperature of the oil-bath is then raised until some of the fuel begins to distill off. The most volatile portions of the fuel in the flask are the first to be boiled-off and condensed. We keep running in fresh fuel containing both high and low ends to keep this level constant, as indicated by the hook

[1] See The Journal, November, 1921, p. 313.

gage. The boiling-point gradually rises because equal amounts of high and low are coming in and we are distilling off more of the low. Finally, after ½ or ¾ hr. of this continuous process, the boiling-point of the liquid in the flask becomes constant, which shows that the composition of this liquid is no longer changing. Since neither the amount nor the composition of the fuel is changing, the input of fuel must be the same as the output. In other words, we are putting in the original gasoline and taking out the vapor of completely vaporized gasoline. Furthermore, this liquid in the flask is in equilibrium with the completely vaporized gasoline, and therefore has the same composition as the first drop to condense, or the last drop to be vaporized, under the conditions prevailing in the manifold.

By this method, however, we have been able to get, not a single drop, but a whole flask full of gasoline which has integrated the distillation-curve of the fuel exactly as it is done in service. We can take samples of this "equilibrium mixture" and determine its vapor pressure and the temperature at which it would be completely volatile for a given mixture-ratio and pressure, or the pressure at which it would begin to condense if we started to cool the completely vaporized mixture. In this manner we have made a thorough study of the characteristics of a number of typical present-day fuels, ranging from aviation gasoline to Socony kerosene.

The 85-Per Cent Point

In general, we have noted that the average boiling-point of the equilibrium mixture in which we are interested approximates the 85-per cent point of the original fuel, and we have found furthermore that by subtracting 135 deg. cent. (243 deg. fahr.) from the 85-per cent point in the ordinary distillation we can approximate the condensation temperature of a 12 to 1 mixture. It is obvious, however, that this is at best merely a rough approximation; its principal value is to indicate that the 85-per cent point comes nearer to determining the effective volatility of a fuel than the 50-per cent, the 90-per cent or the end point, which are more frequently used for the purpose.

While the preparation of the equilibrium mixture is a simple proposition, the measurement of its vapor pressure is rather difficult and not at all well adapted to routine tests, although it can be carried out in any laboratory if sufficient care is taken. We have therefore tried to find out whether it might not be possible to get a fairly good approximation by subtracting a constant amount from the final constant-temperature obtained in preparing the equilibrium mixture. A little consideration of the thermodynamics involved will show that this could not be true for fuels containing the higher-boiling alcohols or for any fuel differing greatly in composition, although for paraffins and naphthenes not excessively unsaturated it should hold fairly well. Actually by subtracting 120 deg. cent. (216 deg. fahr.) from this equilibrium boiling-point it is possible to obtain the condensation temperature of five or six fuels tested, with an average deviation of only 3 deg. cent. (5.4 deg. fahr.) as compared with an average deviation over twice as great for the 85-per cent point method. The single exception to this rule in the six fuels tested was in the case of Red Crown kerosene whose Baumé compared with its boiling-point showed conclusively that it was far outside the range of composition of ordinary gasolines or paraffin kerosenes. For all ordinary motor fuels it would appear, at least until further evidence is secured, that this approximation is entirely satisfactory.

To make the method of preparing the equilibrium solution somewhat simpler, the maintenance of the constant level in the distillation flask shown in Fig. 1 has been made automatic by the use of the sleeve-valve and the floating flask as shown. It is merely necessary to keep the temperature of the oil-bath roughly 40 deg. cent. (72 deg. fahr.) above that of the liquid boiling in the flask, and to use a small, well-ground sleeve-valve that feeds in liquid when the flask rises slightly and shuts it off as soon as the flask begins to sink. The temperature and level of the oil bath must be kept reasonably constant to enable this to be done. For ordinary work, however, it is easy enough to control the level in the flask by operating the stop-cock by hand.

By this means we have apparently a simple and reasonably accurate method of determining the "condensation temperature," or what we may call the "effective end-point" of the fuel. Complete vapor-pressure measurements must, however, be made on several more fuels from different sources before the accuracy of the recommended approximation can be considered as established.

Ease of Starting

Let us consider next the volatility of the fuel so far as it affects the ease of starting. The effective volatility for this purpose is different from that which we have been discussing, since we require only *partial* evaporation of the fuel to get a mixture rich enough to ignite, and this volatility depends primarily upon the initial part of the curve, although not on the initial point nor on any single point on the curve.

To illustrate how far in error we may go by taking the initial boiling-point of a fuel as a measure of its ease of starting, consider three fuels which have almost identically the same boiling-point, alcohol, benzol and a hypothetical paraffin hydrocarbon with a boiling-point of 80 deg. cent. (176 deg. fahr.) whose properties are determined by interpolation on the assumption that it is 60 per cent normal hexane having a boiling point of 68 deg. cent. (154 deg. fahr.) and 40 per cent normal heptane with a boiling-point of 98 deg. cent. (208 deg. fahr.). It is generally realized that it is much harder to start on alcohol, but the causes therefor have never, apparently, been analyzed in detail.

To represent the situation clearly, Fig. 2 has been drawn. In this curve the logarithm of the vapor-pressure of the three fuels has been plotted against the reciprocal of the absolute temperature, but the numbered coordinates show the vapor-pressure in millimeters of mercury and the temperature in degrees centrigrade and fahrenheit corresponding thereto. The advantage of plotting in this way is that the vapor-pressure curve is substantially a straight line and its slope is determined by the heat of vaporization of the fuel.

It will be noted that the three fuels have a vapor-pressure of 760 mm. (29.92 in.) at very nearly the same temperature; in other words, they have the same boiling-point. For the purpose in hand, however, we are interested in much lower vapor-pressures corresponding to the leanest mixture which will ignite, which is in the neighborhood of 11 mm. (0.43 in.) for the paraffin hydrocarbon. The rate of change of vapor-pressure with temperature therefore becomes an important item in determining the relative ease of starting, and it will be noted that the vapor-pressure of alcohol drops off much more rapidly than that of benzol or the paraffin hydrocarbon; in other words, while all the fuels require about the same temperature to give a vapor pressure of 760 mm. (29.92 in.), the alcohol must be 15 deg. cent. (27 deg.

fahr.) warmer than the paraffin hydrocarbon to give a vapor pressure of 11 mm. (0.43 in.).

Ignition

The second difference between the fuels is in the richness of the mixture necessary to make ignition possible. The paraffin hydrocarbon and benzol are very similar in this respect, but the molecular weight of alcohol is so much lower than that of the other fuels that the required vapor-pressure is nearly three times as great, as shown by the *vertical position* of the horizontal lines for each fuel in Fig. 2. This is again unfavorable to the alcohol as far as ease of starting is concerned.

Heat Required for Evaporation

The third difference between the fuels is in the amount of heat that they require for evaporation. If a fuel and a stream of air are brought separately to the same temperature and then mixed, there will be a very marked cooling, due to the absorption of the heat of vaporization as the fuel evaporates into the airstream. This cooling in the case of gasoline generally amounts to around 15 deg. cent. (27 deg. fahr.). In the case of alcohol, however, due to the higher heat of vaporization per molecule and the larger number of molecules to be vaporized, this factor becomes about 50 deg. cent. (122 deg. fahr.).

The *length* of the horizontal lines on Fig. 2 therefore indicates the temperature to which the air and fuel must be separately heated in order that after vaporization and the resultant cooling they shall have just the proper vapor-pressure to make starting possible.

A combination of these three factors, as indicated graphically in Fig. 2, shows that if the paraffin hydrocarbon has a given ease of starting at —2 deg. cent. (28 deg. fahr.), the benzol would have to be heated to +4 deg. cent. (39 deg. fahr.) and the alcohol to + 66 deg. cent. (151 deg. fahr.) to give equal ease of starting, in spite of the fact that their boiling-points were identical within a degree. The *absolute* temperature at which they would start depends of course upon other factors, such as the compression, etc.

The above-stated enormous difference between two fuels of the same boiling-point illustrates very clearly the futility of the present type of boiling-point specification to cover the varying types of motor fuels with which we will have to deal in the near future. Even for ordinary mixtures of paraffin hydrocarbons with similar heats of vaporization, etc., the custom of looking upon the initial-point as the determining factor in the ease of starting is indefensible, except for the rare case where the engine cylinders themselves are flooded with a large excess of the liquid fuel, so that the air is saturated with the fuel without appreciable change in the composition of the remaining liquid. The much commoner practice of using a choke or injecting gasoline into the manifold results in the vaporization of probably one-fourth or one-third of the fuel, and the vapor pressure of the liquid remaining thereafter is the determining factor in the volatility, so far as it affects the ease of starting. Again, this does not correspond to the 25-per cent point or the 33-per cent point on the ordinary distillation-curve, but it is rather an effective integration of the lower end of the curve when, say, 25 or 33 per cent of the gasoline has been distilled off into an airstream which is in contact therewith.

Alternative Apparatus for Determining Volatility

For an approximation probably covering most hydrocarbon fuels without serious error, we have found it possible to obtain a similar type of equilibrium solution by modified procedure, using the apparatus shown diagrammatically in Fig. 3. In this case we start with an empty flask in the oil-bath and continually run in 10 parts of fuel and distill off three, the remaining seven parts gradually filling the flask. If this is done carefully the boiling-point remains practically constant, once the flask is full enough to cover the thermometer. By the same method of reasoning as that used in the previous discussion the composition of the liquid in the flask corresponds to that of a drop in a manifold from which 30 per cent of the fuel has been evaporated, which may be taken as an average condition for starting in cold weather by the use of a choke or priming in the manifold.

In this case it is more difficult to regulate the input of the fuel by hand, since instead of maintaining a constant level we must now keep the ratio of the incoming

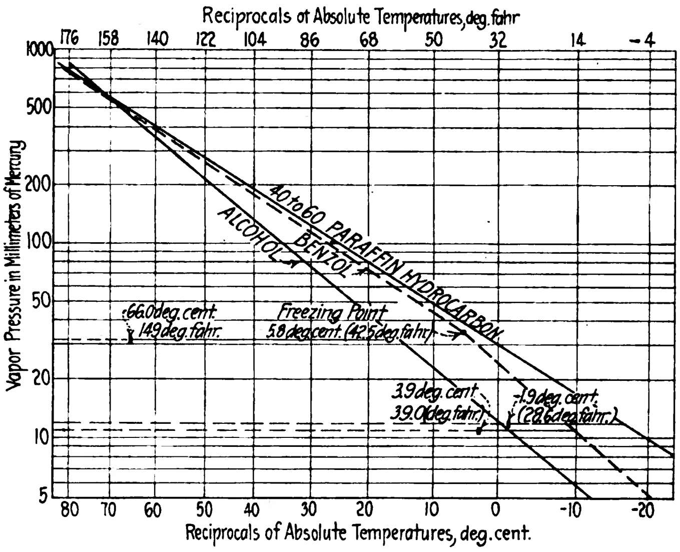


Fig. 2—Vapor-Pressure Curve Plotted to the Logarithm of the Vapor-Pressure and the Reciprocals of the Absolute Temperature

The Advantage of Plotting the Vapor-Pressure Curve in This Way Is That a Straight-Line Form Is Obtained and the Heat of Vaporization of the Fuel Determines the Slope of the Line

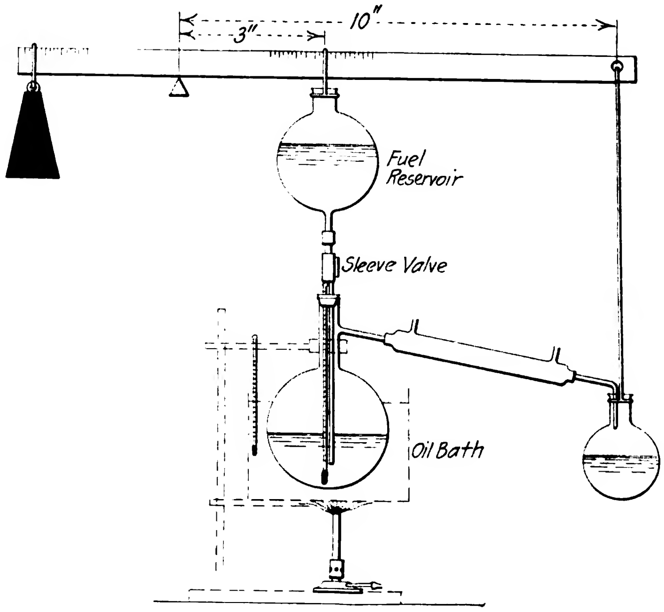


Fig. 3—Apparatus for Determining the Volatility of Motor Fuels

and the outgoing streams constant 10 to 3, but this can be done automatically by the balanced-beam device and sleeve-valve shown in Fig. 3. When three parts of fuel reach the collecting-flask the beam drops, letting in gasoline from the reservoir until 10 parts have been admitted through the sleeve-valve, thus balancing the beam again. Only preliminary results have been obtained thus far with this apparatus, so that we are not able to say how the results compare with the various points on the ordinary distillation-curve.

Determining Partial Vaporization

However, to really measure the effective volatility of the fuel for starting, and to check up the validity of the above-suggested method of measurement, we have devised still a different apparatus, shown diagrammatically

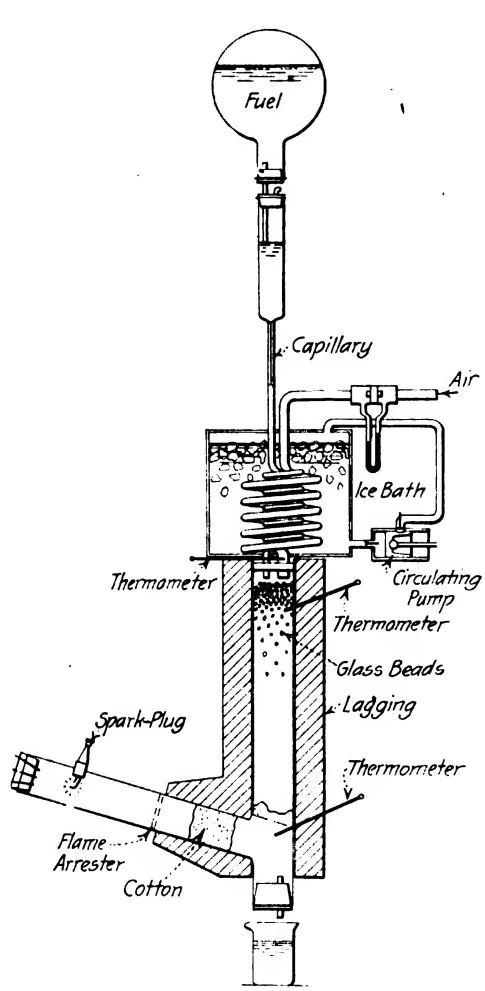


Fig. 4—Apparatus for Determining Partial-Vaporization Temperatures

in Fig. 4, which attempts to take into account by a reasonably simple laboratory method all the factors in which fuels may differ as to their ease of starting. The method consists essentially of continuously passing a stream consisting of five parts of air and one part of fuel, by weight, to approximate the average ratios used in starting with a choke, through an ice-calcium chloride bath whose temperature can be controlled by circulation, and then allowing the two streams to mix in a lagged column of glass beads. By this means the gasoline is cooled by evaporation as it would be in a manifold and the air becomes saturated with the lighter constituents of the fuel. All the *liquid* fuel passes out at the bottom, suspended drops being removed by the plug of cotton. The stream containing the vaporized portion of the fuel then passes a spark-plug which is operating continuously. The temperature of the ice-calcium chloride mixture in the bath is then gradually raised until the first ignition in the exit tube is secured, and the temperature of the air leaving the ice-bath at that time, which should be practically identical with that of the fuel and the bath, is taken as the effective starting-temperature of the given fuel.

Cooperation Sought

As indicated above, we are only now starting work on the measurement of the effective volatility by these methods and can say nothing as to their validity or, indeed, as to whether the apparatus may not require considerable modification to give reliable results. I am presenting these preliminary results and ideas at this time, however, in the hope that both producers and consumers of motor fuels may realize the inadequacy of present methods of testing and specifications, and that many laboratories may unite in trying to work out testing methods that really measure the properties in which we are interested.

If satisfactory tests based on these methods can be worked out, it will do away entirely with the need for specifying five points on the distillation curve. We will require just two tests, one for starting volatility and another for what we may call "distribution volatility" or "effective end-point," which also largely determines economy and crankcase dilution.

As I have indicated, our laboratory has no desire to stake out this field of investigation for itself, but rather hopes that as many laboratories as possible will follow up the suggestions and make such improvements as may occur to them until enough data are collected to make possible the evolution of a definite standard method of conducting the tests. We will be more than glad to cooperate with other individuals and laboratories to this end.

H. L. HORNING

Representing the National Automobile Chamber of Commerce and the Society of Automotive Engineers, H. L. Horning gave an address on the responsibility of the petroleum and the automotive industries to the public. He said:

No industry should make the error of assuming that its own house is swept clean and it is therefore proper to say that if motor fuel and lubricating oil marketed today are not perfect, there are many details of engine design, construction, sale and service that can be improved. There are limitations beyond which petroleum technologists cannot go, due to the physical and chemical nature of the petroleum products and to economic influences. There are likewise limits beyond which the automotive engineers cannot go, set by the laws of mechanics, thermodynamics, chemistry and physics, and the peculiarities of human nature. During the last two years the automotive industry has endeavored to vaporize fuels more effectively, and there has been an effort on the part of the petroleum industry to arrive at uniformity in fuel specifications.

The efforts of the automotive industry to vaporize the fuels that have been available in the last few years cannot be considered entirely successful. Even the cars that it is believed have the best systems may show more liquid in the crankcase after running 500 miles than at

the beginning. Oil consumption can be measured only by the amount of oil supplied since the last complete filling after draining. There is no definite way to tell how much real lubricating oil is used as such, between two fillings. The dilution of lubricating oil by the unvaporized and partially burned fuels is considered by many of the leading automotive engineers a measure of the failure to vaporize, and of the decreasing volatility of the fuels. The wide variation in the distillation curves of the fuels reported on by the Bureau of Mines in its last fuel survey indicates that there is no single known device that will vaporize both the lightest and the heaviest of these fuels in an equally satisfactory manner. The service departments and engineers of some companies are at the very end of their technical resources in countering the results of the decreasing volatility.

It may be well to consider what fundamental characteristics of fuels, lubricating oils and engine design made possible the petroleum industry with its vast trade in motor fuels and lubricating oils, and the automotive industry producing passenger cars, trucks and tractors.

FUEL CHARACTERISTICS

(1) Liquid fuel of high volatility
(2) Fairly uniform viscosity
(3) Chemical purity
(4) Stability of chemical structure
(5) High energy-content
(6) Wide marketing at a low price

INTERNAL-COMBUSTION-ENGINE CHARACTERISTICS

(1) Reliability of four-cycle design
(2) Well understood design
(3) Easy operation by persons of a widely varying intelligence
(4) Successful operation under greatly different conditions
(5) Accessibility and ease of repair
(6) Low cost of maintenance
(7) Light weight
(8) Low selling price, relative to the means of a large number of people to whom the economic value is great

CARBURETERS

(1) Reliability in metering, atomizing and vaporizing the fuel
(2) Simplicity and low number of parts easy of adjustment

IGNITION

(1) Reliable spark-plug easily cleaned
(2) Simple, practical generating system

LUBRICATING OIL

(1) Sufficient stability to prevent disintegration or vaporization
(2) Sufficient body to keep moving elements apart
(3) Adequately low internal-friction or viscosity
(4) Wide marketing at reasonable cost

LUBRICATING SYSTEM

(1) Practical lubrication of moving parts with a fairly wide range of oil qualities
(2) Distribution of oil in satisfactory quantities
(3) Assured practical lubrication over wide ranges of temperature, load, speed, service and neglect

All the years of development and experience from 1900 to 1922 have not shown that we can deviate in the slightest degree from these fundamentals without lowering the economic value of automotive apparatus to the public.

I have asked a great many well-informed men where they thought the industries would be today if, instead of utilizing the reliable four-cycle engine and the volatile fuels, we had built the Diesel engine, with which volatility, the carbureter, the spark-plug and the ignition system are not necessary. The average answer has been that we would be at about our 1903 development.

Volatility the Main Dependency

The volatility of the 1900 to 1910 gasoline made up for the imperfect design of the carbureters of those days. Of all the physical characteristics of motor fuel, volatility was and still remains our main dependency in the operation of motor vehicles of the type that has proved to be practical in meeting the demands of modern times.

Professor Wilson, of the Massachusetts Institute of Technology, has done our industries and the public a great service in pointing out technical methods by which the condensation points of the vapors of fuels of various distillation characteristics can be determined with accuracy. These tests appear to many to be the best approach to a true understanding of volatility yet available.

There has been great complaint of the sudden increase in content of highly volatile fractions in motor fuels in the United States during the last summer and fall, as evidenced by the low initial boiling-points given in the Bureau of Mines' reports and by a variety of experiences recognized by motorists who know and suffered by those who did not know. Nearly all modern carbureters meter the liquid fuels through nozzles or orifices of various shapes which give accurate results under definite predetermined conditions. The gravity and the viscosity of the fuels are of most striking economic importance in this connection. Viscosity is determined by the internal-friction of the fluid. In a nozzle, viscosity governs the amount of fluid flowing under given pressures and temperatures. Temperature changes the viscosity in a rapid and marked manner.

Gravity and Viscosity

There is a difference in flow of from 5 to 25 per cent with the carbureters now in use between temperatures of 60 and 90 deg. fahr. in the case of fairly volatile fuels. There is a great change in viscosity with changes in gravity and volatility. There is a difference of 10 per cent in the flow of the fuels in the extreme cases of the Bureau of Mines' report. The higher the gravity, or molecular weight of any fuels of similar origin or structure is, the higher the viscosity is, and the less the flow with a given nozzle, as well as the volatility. The less volatile the fuels are, the greater the viscosity and the less the flow through any given nozzle are. During periods when you oil men want to work off heavy fuels, or have a shortage of volatiles, the public simply has to open up the gas to run. May the Lord help the man who has a fixed-nozzle outfit!

However, in periods like the last summer when you wanted to move volatiles, nothing happened except that unawares the average man found he was making 13 instead of 15 to 16 miles to the gallon and some touring individuals had to walk 5 miles or so for fuel because their fuel supply ran out ahead of time. It is impossible to estimate the amount of good fuel wasted this year due to the low viscosity attending your effort to move highly volatile fuels, and I suspect that an appreciable part of your record of a recent month in which you were reported to have marketed 500,000,000 gallons of gasoline was due to its low viscosity in the hands of an unknowing public.

Uniformity Essential

Now this fact is above all others the one that imposes on the petroleum industry the entire weight of a high

moral responsibility for a uniformity in the marketing of motor fuel, both as to volatility and as to viscosity. It is not my place to moralize with you, but it is fitting for both our industries to ask if it is fair, I will put it even stronger, American in spirit, to foster a trade wherein the public is served with so varying a quality. I wonder how many oil companies took the trouble this last fall to have their tank-wagon and service-station men tell their customers they could cut down the fuel feed. A simple service this but, I fear, a neglected one. I make a plea for uniformity in volatility and viscosity, and can promise an improvement in mileage and a satisfactory saving in first cost and up-keep of automotive apparatus, if you will see that this uniformity is approached.

Let us now consider the total losses imposed by fuel and engine limitations. If there were no losses whatsoever, it would be possible to get a brake mean effective pressure of 582 lb. per sq. in. of cylinder area. The highest attainable brake mean effective pressure is, after all losses are deducted from the maximum possible pressure, only from 25 to 15 per cent of this figure, depending upon the type of engine and of fuel.

Chemical Stability

Referring back to the fundamental analysis of the characteristics of motor fuel that made our industries possible, I call your attention to the matter of chemical stability, that quality which permits the fuels to be burned at high compression and in such an orderly way as to give high thermal efficiency. I will not dwell on this matter more than to say that the tendency to knock arising from chemical instability is largely responsible for the low compression commonly used and for a loss of 23 to 50 per cent in mileage. This fuel defect can be overcome to only a relatively small extent by improvement in engine-cylinder design. The great deposits of carbon encountered in the use of latter-day fuels is due in a large measure to this Bolshevik tendency of the fuel. With lower volatility comes increased knocking, necessitating lower compression and lower efficiency. With the knocking tendency eliminated, smaller engines could be used and operated more nearly at their full-load capacity. Messrs. Kettering and Midgley have accomplished results in the last year along the lines of discovering correctives for this defect in the fuels, which in time cannot help being considered epochal.

The petroleum industry has fallen into the error of vindicating the lower volatility on the ground of a higher energy content of the fuel expressed generally in British thermal units. The high energy would be gratifying if available. Some facts of importance to the petroleum industry were arrived at this year by Harry Ricardo in a very thorough investigation of fuels for the Asiatic Petroleum Co. of Great Britain. These facts may be stated briefly as follows:

> In general, when all hydrocarbon fuels are tested under the same conditions, in which sufficient heat is applied to vaporize them, and at compressions at which the most unstable will not detonate, it is found that they give the same power and thermal efficiency within 1 per cent, and this power is attained with a mixture giving complete combustion. There are many characteristics of the fuel, as well as limiting factors in engine design, that make the heat energy available only in a limited degree. Claims for great power in fuels marketed are of doubtful accuracy. Those fuels that have the higher volatility and stability always tend toward a greater return from the energy in them than those of low volatility and inferior stability.

Questionnaire Results

I wrote fourteen executives engaged in the automotive industry, who not only are leaders but have an economic as well as an engineering appreciation of the questions involved in the fuel problem. I will give a recapitulation of their answers. I am not going to draw any conclusions from them for you, for I believe the individual answers should have your serious consideration. Abbreviating an observation set forth by Schopenhauer, you will probably act on these, on an impulse having its origin in your character, rather than in the influence of your knowledge of the facts.

The questions and answers are as follows:

Question 1—What percentage of all the fuels wasted is due to the high end-point?

Answer—The greatest losses occur during the starting from cold, running, idling and accelerating.

The losses are least with highly heated vaporizing systems and may show a difference of only 3 per cent.

With the average motor car 30 per cent of the waste is due to high end-point.

Lower end-point would reduce crankcase dilution. One engineer says that there is a direct waste of 20 per cent due to high end-point in the average engine, but that the indirect result of high end-point may be as much more waste.

One claims a 60-per cent loss during the starting and warming-up period, or generally during cold-period running.

With highly efficient manifolds Navy-specification gasoline can be made to operate with very little loss, as compared with 350-deg. fahr. end-point fuels, if it is kept uniform.

Question 2—What percentage of fuel waste is due to the effort of the user to prevent knocking?

Answer—Probably 2 per cent of fuel is wasted by rich setting for heavy pulling, and 28 per cent by best setting for power.

Some waste is due to improper setting of the spark.

Question 3—What percentage of fuel wasted is due to the necessity of low compression-ratio?

Answer—An increase in mileage of from 30 to 100 per cent is possible with higher compressions.

Question 4—What percentage of fuel waste is due to overall conditions?

Answer—Motor cars would use 16 per cent less fuel if uniformity in fuels prevailed.

There is a 28 per cent loss due to the effort to get maximum power.

It is possible to increase the mileage 60 per cent with uniform fuels.

Question 5—Does the standard Navy specification, 120 to 440 deg. fahr., represent a practical fuel today?

Answer—It is a satisfactory standard for a uniform fuel and the limit for present automotive equipment. It can be handled well with good hot-spot manifolds. One engineer says that it is practical but not desirable for average cars or conditions. One advises the installation of a separate tank for starting-gasoline of 72 deg. Baumé for winter.

Question 6—Is the last 10 per cent coming off from the distillation of Navy-specification gasoline responsible for 10 per cent of the power actually delivered, or is there a loss due to the difficulty of vaporizing it?

Answer—The energy of last 10 per cent of heavy fuel can be made entirely available in well-heated manifolds. There is about a 10 per cent loss, not necessarily consisting of the last 10 per cent, but largely due to it, in the average manifolds with

higher end-point fuels. Some engineers claim that the last 10 per cent of fuel is of no value and that 400 deg. fahr. is the maximum end-point for practical fuels.

The complaint today is of much higher end-point.

QUESTION 7—If the end-point of fuels were increased 10 per cent, what percentage of the energy in the 10 per cent of heavy fuel would be available in the average car now in operation?

ANSWER—Little of the 10 per cent of energy would be available with cold manifolds and during starting and cold running even with hot manifolds.

With uniform fuels an engine could be produced to burn fuels of 480-deg. end-point, but no engine is so equipped now.

QUESTION 8—Is there a growing demand for fuels containing aromatics and naphthenes?

ANSWER—Yes, even at a higher price.

QUESTION 9—If fuels had an end-point of 350 deg. fahr., would less gasoline be consumed per mile? What percentage less?

ANSWER—There would be more mileage, up to 25 per cent, with proper readjustment of carbureter.

There would be a saving, particularly in starting and in cold operating.

Without change of carbureter adjustments there would be a decrease in mileage with light fuel in summer, but an increase in winter.

With proper manifolds there would be no difference after warming-up.

QUESTION 10—If large quantities of fuel with aromatic content were available, would the public drift to it even at higher prices?

ANSWER—The great demand will always be for lower-priced fuel.

There will be a demand for any fuel that will not knock. In the case of engines that knock easily the tendency will be to use the aromatic fuels; cheap petroleum products will be used for those engines that do not knock easily. Those whose engines develop knocks will go to aromatics when the price is not over 10 per cent above the lowest price for fuel. There is a marked growing demand for fuels with aromatic content.

QUESTION 11—What is the percentage difference in the length of service for pistons, rings and cylinders, assuming that 100-per cent service is given with fuel of 350-deg. end-point? The service under consideration is with 440-deg. end-point.

ANSWER—Pistons of out-of-date model will wear twice as long with 350 as with 440-deg. end-point.

With a good hot-spot manifold, they will last 10 per cent longer.

With high temperature of mixture and no detonation there will be little difference; but the fuel would have to be uniform.

Very often dust is the cause of wear assigned to high end-point fuel.

QUESTION 12—How much more lubricating oil will be used, due to dilution on the cylinder walls and in the crankcase, when using Navy-specification gasoline than when using 350-deg. end-point fuels?

ANSWER—Dilution increases with end-point.

The oil has to be changed more frequently with increase in end-point; hence there is greater oil waste.

There is little dilution with 350-deg. end-point gasoline.

Efficient hot-spot manifolds reduce dilution and the consumption of lubricating oil.

Dilution occurs mostly in starting, in cold-weather running and during warming-up.

On some engines the lubricating-oil consumption will be double with 440 as compared with 350-deg. end-point gasoline.

Design can control this for a uniform fuel.

QUESTION 13—What mileage is lost due to poor compression resulting from the use of 440-deg. end-point fuel, compared with 350-deg. end-point?.

ANSWER—In engines without vaporizing systems the loss is about 25 per cent.

In engines equipped with usual designs of hot-spot it will not exceed 10 per cent.

In engines in which the intake manifold is raised to very high temperatures with some of the products of combustion, it is possible to burn 530-deg. end-point fuel without defects in compression.

Reverting again to the fundamental analysis of the cause of the rapid development of our industries, I want to present a review of the conditions that confront the sales, service and engineering departments of a company whose apparatus must meet the varying fuels which your decisions dictate. Let me dispose of the carbureter by stating that long ago it lost its originally intended function of vaporizing the fuel. As an instrument for metering the fuel and air it has reached a high state of development. Nothing except a manual control of fuel flow has been devised to meet the widely varying viscosities imposed by temperature conditions of our climate and changes imposed by the engine; or the varying viscosities in the fuels on the market. If a fairly uniform volatility could be attained by the petroleum industry, a fixed-jet carbureter could be used that would remove one of the causes of greatest waste, namely, a gasoline adjusting-valve in the hands of an unskilled, forgetful and in a measure irresponsible public. This would eventually save gasoline in a considerable quantity. The certainty of a uniform fuel would permit manufacturers to solve problems such as dilution of crankcase oil and rapid wear of parts.

Temperature variations can be met practically with uniform fuels by vaporizing devices of high overall efficiency, excellent distribution being attained. The devices cannot be efficient with a wide variation in volatility and viscosity.

SIMPLICITY A PRIME CONSIDERATION

The automotive industry has found that it cannot depend upon the intelligence or care of the public for complicated adjustments. The devices that make good are those in which there is no adjustment. The most successful engine is that which continues to operate without adjustments over long periods. Whether this is right or wrong is immaterial. The economic significance of this simple fact overshadows every other phase.

The loss due to interrupted service of automotive apparatus is, irrespective of cause, a loss to national wealth which is sustained by the public in general and by the automotive and the petroleum industries in particular. This is a most significant feature of our mutual problems. If we make highly technical apparatus to meet the rapidly varying qualities of fuel, we will defeat our very object in the hands of the public.

The replies to a questionnaire sent to 20,000 car owners by the National Automobile Chamber of Commerce indicate that the preferential basis on which cars are bought is as follows:

	Per Cent		Per Cent
Endurance	18	Flexibility	7
Comfort	11	Hill-Climbing Ability	6
Price	10	Endorsement	6
Appearance	9	Specifications	6
Economy	8	Speed	5½
Service	7	Appointments	5½

We plead with you for uniformity of gasoline volatility on the ground of the improvement that will come in the operation of the apparatus in reference to endurance, comfort, economy, service, flexibility and hill-climbing ability, the combined percentage of which is 57.

More than anything else the reliability, what the public calls endurance, is responsible so far as the engine is concerned for the rapid growth of the industry. From a practical standpoint that engine is the best which will give satisfaction even when it is in a dilapidated condition. The service value outweighs the matter of efficiency. As times change and fuels rise in price the question of efficiency will gain in importance.

Lubricating Oils

Lubricating oils, which were so important at the beginning of the industry, have become one of the most vexing problems with the decline in fuel volatility. The president of one of our best known motor car companies has made the statement that during the years 1918 and 1919 the problems of piston and cylinder lubrication cost that company $1,000,000 in service. In the last year several firms have rebuilt their engines as many as three times to stop oil-pumping. Lubricating oils have been variable in viscosity. The automotive industry would like to cooperate with the petroleum industry in arriving at a reasonable specification for certain services and then have the petroleum industry stick to it. We regret to state that the variations in lubricating oils in the last 5 years, even among those most widely used, are drastic. As fuels have decreased in volatility it has been increasingly important to have oils of greater body to offset the dilution. Heavy lubricating oil is an important cause of loss in mechanical efficiency and of increase in fuel consumption.

Many systems of lubrication have been developed. The final forms of these must

(1) Give satisfaction irrespective of oil and fuel qualities
(2) Require little or no attention by the public
(3) Be almost automatic

These factors tax the best ingenuity of the automotive industry and lead to very unfavorable compromises. Here again uniformity in fuels and oils would be of immense value in the operation of engines.

Saturation Point and Fuel Famine

In conclusion, let me assure you that the automotive industry believes that it will be many years before there will be saturation of the market for passenger cars, trucks and tractors. In the last year many new uses have been found for the internal-combustion engine. During the coming year probably more cars will be produced than were produced last year, when the output was approximately 1,200,000, of which 800,000 were Fords.

There is a growing belief in the automotive industry that there is no real danger of a fuel famine. The immense reserve in technical and scientific possibility promises that the incentive alone will be needed, as the near-famines threaten, to meet the demands of many succeeding generations. There is, however, no justification for the present waste on the basis of no threatened shortage of fuels.

A study of the natural processes by which the energy of the sun was stored up millions of years ago in the form of what we call petroleum indicates that by scientific methods the energy reaching us can be caught and marketed each year, as in the case of food. This is the resource to be depended upon when new fields shall have ceased to respond to the incentives that actuate fortune-hunters.

Fuel Marketing Policy

The automotive industry offers for your serious consideration the following policy in the marketing of motor fuel. If you will see that the poorest fuel offered for sale is close in volatility and viscosity to Navy-specification fuel, the most disturbing variable will be eliminated from the fuel problem before the automotive industry. Your undertaking to do this will insure greater satisfaction in the operation of the 10,000,000 cars out today. The life of the wearing parts will be prolonged. This uniformity will go a long way toward solving your lubricating-oil problem. You will by this act stabilize the growth of the automotive industry, conserve a great quantity of fuel, decrease the engine-upkeep cost, and reduce the depreciation rate.

I believe that business in America is today on the highest moral plane that the world has ever known. I believe that business and particularly big business is being conducted on a thoroughly sound ethical basis. I believe that more transactions are being conducted on the basis of good faith between individuals than has been thought possible. I believe that there is a new aristocracy among men and nations who prove daily that a man's word is the limiting factor in the value of a contract or a treaty. I rest the case on this faith, leaving it to the decisions of your conscience.

I would have you consider carefully an economic truth. No transaction is economically sound that does not recognize two profits, that of the buyer as well as that of the seller. It is the buyer's profit that in the long run determines the measure of the seller's prosperity and stabilizes the market. It takes strong conviction and splendid courage to accept this truth at its full value and to act on it. Yet our industries cannot serve the public fully by adopting any compromise that will not insure to the public the maximum returns arising out of uniformity in fuels and lubricating oils and the very best engines that this uniformity will promote.

ROADS

GRANTING that the preparation of the roadbed has been properly done, many kinds of highway surface will give excellent service. The element of time is important. There are so many miles of highways to be constructed and their cost will be so enormous that the most careful and detailed study of each highway project must be made to provide, at the lowest possible cost, highways that will give satisfactory service and can be maintained without undue depreciation under the traffic that is to use them. Many times the question has been asked, what type of highway is best? The answer is, there is no one best kind or type of highway surface.

Subgrade, drainage and present and prospective traffic, vitally affect the determination of the standards of construction to be used. There must be a careful analysis of the engineering and economic conditions for each particular case to determine the kinds of material that can be used successfully, and after these facts are determined the various types of construction that can be used economically should be brought into competition to secure the best possible results. The cost must always be considered in determining the type of highway surface to be used, and the allowable cost must be determined by the traffic that is to be borne. Local conditions vary to such an extent that very careful consideration must be given to all the factors that have a bearing on each individual project.—T. H. MacDonald.

The Trend of Aviation Development

By J. G. VINCENT[1]

GROUPING the influences that are retarding the development of aviation into five specified divisions, the author, who took a prominent part in the development of the Liberty engine and other wartime aviation activities of the Government, discusses each one, in the order of their importance, in an effort to point out the limitations that exist as differentiated from misconceived non-existent limitations and to indicate remedial measures stimulative to a provident trend and vigorous growth of aviation.

The subjects of adequate landing-fields, the real and imaginary dangers of flying, single and multi-engine airplanes, passenger comfort and commercial considerations are treated at some length, prefatory to an outline of the trend of airplane design and an enumeration of powerplant requirements. With an outlook toward future development, the essentials of air transportation are commented upon specifically under four divisions inclusive of landing-field policy and Governmental mail-contract patronage and experiment-station helpfulness as aids to successful progress.

IN view of the embryonic state of the art of aeronautics, I am inclined to attack the subject of the trend of its development with more or less diffidence, recognizing that future developments may rudely shatter such prophecies as I may have the temerity to submit. However, the best we can hope to do is to try to visualize ideal attainments as we conceive them in the light of our present knowledge; with such concrete examples before us we can speculate more accurately on the future course of development.

Before entering into a discussion of the various elements of the airplane, I would like to review the present art of flying, pointing out the limitations that exist and attempting to eradicate misconceptions as to limitations that do not exist. Whenever the subject of flying is under discussion we hear queries as to why aviation does not progress, why the Government does not do this or that to encourage aviation. I believe firmly that aviation is developing as fast as the state of the art and existing conditions will permit. While I must say that at times the outlook is by no means encouraging, yet on second consideration it is apparent that aviation is following the same inflexible rule that has governed the development of all our transportation facilities. Aviation *must* be made to pay its way; it cannot be coddled on Government subsidies; it cannot be nursed along in half-hearted competition with the older forms of transportation; it must prosper on its own merit or not at all. The time is bound to come when we will consider, not whether we can afford to use the plane, but whether we can afford *not* to use it. The steamboat, the railroad, the automobile and the motor truck have all had to fight and fight hard for recognition, and the airplane will have to continue to fight its battle until a truly successful state of development shall have been reached.

The influences that are retarding the development of aviation can be grouped as follows, in the order of their importance: (*a*) lack of landing-fields and other facilities for storage and repair; (*b*) the more or less prevalent impression of the dangers connected with flying; (*c*) the lack of comfort for passengers; (*d*) the unsuitability of the average plane for commercial purposes; and (*e*) the difficulty of interesting capital in organizing aviation transportation due to (*a*), (*b*), (*c*) and (*d*). I propose to take up each of these factors in turn and to attempt to point out how, in my estimation, the conditions cited can best be remedied.

LANDING-FIELDS

The absence of suitable landing-fields in proximity to our larger cities represents the one obstacle that the aviation industry cannot hope to remedy unaided. Federal or municipal aid in this direction is essential and is warranted just as much as is the expenditure for good roads, which will total approximately the fabulous sum of $600,000,000 in 1921. None of this amount is contributed specifically by the automobile industry; the country at large pays and receives the benefit from it. Similarly, it is not to be expected that the struggling aircraft industry can take any part in building up a system of landing-fields throughout the country. This phase of the situation was covered thoroughly in the report of the National Advisory Committee for Aeronautics, which was endorsed by the President and submitted to Congress last April.

Before leaving the subject of landing-fields, I would like to record a suggestion that I believe will be very much appreciated a few years hence. That is, landing-fields should in all cases be equipped with permanent hard-surfaced runways of ample width and length and preferably arranged in the form of a cross so as to permit of landing in at least four directions. Commercial aviation will never be entirely successful until flying can be carried on more or less without regard to weather conditions; at this time soft landing-fields are responsible not only for the postponement of many flights, especially in the spring and winter months, but also for frequent damage to airplanes caused by "nosing over" in soft fields. The use of hard-surfaced runways such as are found at McCook Field, Dayton, Ohio, appears therefore to be vital to the success of all-the-year-'round safe flying. Furthermore, these runways offer excellent landmarks when viewed from the air, and it is easier to bar spectators from these well defined areas than from the field at large, thus eliminating another source of danger.

DANGER IN FLYING

I have placed second in the list of influences retarding the growth of commercial aviation the more or less prevalent impression of the dangers connected with flying. These dangers can be classified as real and imaginary. We will consider each in turn, knowing that the real dangers must be overcome by new developments and improvements, while the imaginary dangers must be dispelled from the public mind by suitable propaganda that we can all assist in spreading. First and foremost of the real dangers is undoubtedly that of "stalling." Directly or indirectly, "stalling" is probably responsible for the greatest percentage of fatal crashes. Forward speed is, of course, essential to the sustentation of an airplane and for any given machine at any particular altitude there is a minimum critical speed below which the plane is unable to support itself and will fall out of control for such a distance as is necessary to bring it up

[1] M.S.A.E.—Vice-president of engineering, Packard Motor Car Co., Detroit.

to its minimum flying-speed. This stalling speed is given in terms of *forward* speed in the line of normal flight. Without going too deeply into technicalities it may be stated that in cases where the airplane is not advancing in a direction parallel with the airstream, the stalling speed will be considerably raised since the airfoil section is designed to give the maximum lift when the airstream is substantially normal to the wing.

Sufficient "flying" speed is therefore essential at all times to the safe control of an airplane; and this speed can be attained either from the motive power of the engine or from the force of gravity in the case of a glide. In the case of all machines in use at the present time it has been found necessary, to permit of proper maneuvering when making a landing or taking-off, to provide an excess of control surface, by which I mean that the lateral, directional and longitudinal controls represented by the ailerons, rudder and elevators are of such ample surface that they are effective at speeds below those at which the plane is capable of supporting itself. The consequence is that it is at all times possible for the pilot to manipulate the controls so as to decrease the machine's forward speed down to a point where it ceases to be subject to his control due to lack of sufficient lift developed by the wings. The pilot can then recover control of the plane only by speeding up the propeller if the engine power is available or by gliding a sufficient distance to obtain the necessary acceleration. It is quite evident that if this "stalling" condition is met within a few hundred feet of the ground with a dead engine, the consequences will be serious, since the height is insufficient to permit of accelerating the plane in a glide to the required minimum speed. This possibility of a pilot being able to bring about a stalling condition, which is manifested also in such maneuvers as side-slipping and tail-spinning, represents a phase of aviation that must be eliminated, I believe, before we can say truthfully that air transportation is as safe as the other modes of travel. Some may argue that the expert pilot will never stall a plane even in an emergency, but unfortunately experience has shown that in the great majority of cases when the engine fails shortly after taking-off, which is one of the worst contingencies encountered in flying, even the most level-headed pilot will instinctively try to bring the machine back to the starting-point, instead of "nosing her down" instantly, regardless of the nature of the landing space available directly ahead. Needless to say, if the plane has but limited altitude, this latter maneuver is the only means of maintaining flying-speed and avoiding a stall. Loss of flying-speed is of course not the only cause of a stall or its equivalent; atmospheric conditions, especially just previous to or during a storm, are sometimes responsible, due to eddy currents or sudden variations in the density of the air, which in effect necessitate an instantaneous increase of the minimum flying-speed which will enable the plane to support itself.

The popular conceptions of the dangers of flying center around chiefly the possibility of the engine stopping in the air. As I have just pointed out, engine failure can be regarded as extremely serious only during the few initial seconds after taking-off. A forced landing with a dead engine from any reasonable altitude over ordinary flat country rarely results in serious consequences. At an altitude of 5000 ft., for example, and with a gliding angle of 1 in 10, the pilot has a choice of territory comprising an area of about 280 sq. miles or a circle of 19-miles diameter in which to find his landing spot, and he has ample time to study wind direction, ground obstacles, and the like, before making his choice. Of course, in cross-country flying it is necessary at times to fly over territory on which it would be very hazardous to attempt a forced landing; such as mountain ranges, large bodies of water and rolling country; in such cases the pilot should be guided by common sense and if necessary make a reasonable detour to limit the duration of flight over such territory, at the same time maintaining good altitude so as to have the advantage of a long glide in case of engine failure.

I am not at all ready to admit that engine failure in the air can be regarded as an unpreventable occurrence. As a matter of fact, the majority of engine failures are due to easily preventable causes and can generally be traced to failures in the gasoline, oil or water systems, which in turn are due to lack of coordination between engine and plane design. Unfortunately, these troubles cannot be eliminated entirely in practice until considerable flying experience has been obtained with the particular plane under consideration. In other words, with the expansion of commercial aviation, I would look for a great improvement in respect to the so-called "plumbing" troubles that are responsible, I may safely say, for 90 per cent of engine failures in the air. The automobile went through the same transition in this respect, roadside stops being due almost invariably to similar minor faults.

Failures of the plane structure in the air are now practically unknown. Assuming that a given design has been carefully calculated with ample factors of safety, that suitable static tests of wing-truss, fuselage and controls have been made and that reasonable care is exercised in maintenance and inspection, there exists only a most remote possibility of danger due to the collapse in the air of any part of the plane structure.

We have now considered the elements of danger connected with commercial aviation and are in a position to judge to what extent the popular conception is justified. We must first admit that the results of stalling at low altitude are serious. If this could be obviated, a great step forward in the development of safe air-transportation would be made. Once good altitude has been reached, the element of danger becomes negligible and with a properly designed plane and a well tested and reliable engine properly installed, air transportation can be said to be, if anything, safer than any other mode of transportation. The possibility of engine failure will ultimately become negligible, but this can be brought about only by a large amount of flying. Planes, even today, are perfectly satisfactory from the standpoint of structural safety and improved constructions are being rapidly evolved.

Single and Multi-Engine Planes

It may be well to review at this point the relative advantages and disadvantages of single and multi-engine planes. A few years ago, before reliable engines were available in quantities, it was thought that the best way to guard against engine failure was to provide additional engines or rather divide up the powerplant into smaller units. Two-engine, three-engine and four-engine, and planes with even more engines have been built and successfully flown. A serious drawback to such arrangement is the necessity for providing a surplus of power in the complete powerplant, resulting in uneconomical operation; in the case of a two-engine plane, for example, it is desirable that each engine be capable of maintaining the plane in the air by itself. While the average plane in taking-off from a small field requires more than double the power necessary to sustain it in the air at its mini-

mum flying-speed, nevertheless two-engine planes as constructed heretofore have not been shown to have a factor of safety against engine failure sufficiently high to warrant the added complications. Of course, in many instances the powerplant demands have been in excess of the power of any proved engine and for that reason in large planes it has been necessary to install multiple units of smaller engines. I am not attempting to cover the whole question of single-engine versus multi-engine planes at this time but will state my belief that for intercity transportation over country providing a reasonable number of emergency landing-fields, the single-engine plane is undoubtedly the most desirable. The engine should, however, have 30 or 40 per cent more power than is required for normal cruising speed. For long flights over water, forests, mountains or sparsely inhabited regions, a two-engine plane undoubtedly offers additional security, provided either engine alone is capable of propelling the plane at a sustaining speed.

Summarizing, whereas air transportation offers some risks, these are by no means as numerous as is popularly supposed and in practically all cases they are preventable. Engine failure can never be said to be directly responsible for a crash unless it occurs at very low altitude. Undoubtedly the most serious unsolved problem is how to prevent a pilot from stalling a plane under stress of sudden emergency.

Passenger Comfort

The third factor militating against the progress of commercial aviation is the lack of comfort afforded passengers. This is a real handicap. Although it is not at all difficult to persuade the average person to take his first flight, this is generally accomplished in a spirit of adventure or curiosity. The usual comments made by the passengers upon returning to ground are that the sensation was nothing like what had been pictured; in fact, that the experience was rather mild. The noise of the engine and the propeller are severely criticized and if the trip was lengthy and at considerable altitude the cramped quarters and cold probably receive unfavorable comment. Of course, there have been introduced abroad, and to a limited extent here, planes offering enclosed passenger-accommodation that approaches the luxurious. Much more must be done in this respect, especially in this country where railroad equipment has been developed to a point where one can travel with practically all the luxuries of a hotel at his command. There is nothing inherently impossible in providing similar service through the air, but this would require ample capital and special design throughout.

Probably the most difficult problem lies in suppressing the noise of the engine and the propeller but this also must be done before air transportation can rival ground transportation on the score of comfort.

Commercial Considerations

The fourth unfavorable influence so far as the progress of aviation is concerned was given as the unsuitability of the average plane for commercial purposes. This is largely responsible for the difficulty in interesting capital in commercial-flying ventures. It is fairly well known how wartime machines have been built over in an endeavor to construct a peacetime passenger-carrying plane and also the indifferent results accruing from this procedure have been appreciated. Excellent planes have been built since the war for passenger carrying and many of these are giving splendid service abroad. But the costs of operation and maintenance, as well as the rate of depreciation, of these are so high that it is very doubtful whether any of the ventures based on their operation could pay their own way without the generous subsidies provided by enterprising foreign Governments.

Looking at this matter from a cold businesslike standpoint, we can see that the saving in time afforded by air transportation offers an inducement to the business or professional man that can be measured in just so many dollars. For example, there is a limited demand for extra-fast trains, say, from New York City to Chicago, and the saving in time is considered to more than offset the extra fare paid for this service. It is safe to assume that for still faster service a higher fare in proportion to the extra time saved would readily be paid. Unfortunately, there is a limit to the possible saving in time, due to the fact that long overland trips are invariably made overnight, the average business man considering a night in a Pullman not very much more of a hardship than a night in a strange hotel. The result is that to prove its worth air transportation must save *daylight* hours for the average traveler. Furthermore, even on comparatively short overland trips, of say 200 miles, the average man will prefer going aboard a train at 10 p. m., turning into his Pullman berth and getting up in the morning at his destination, the train having actually been moving perhaps only 5 hr. of the time. On such a run the real inducement to be offered by the airplane is the making of the round-trip in 4 hr., leaving a good part of the day available at either end of the journey for the transaction of business.

Finally, we come to the subject of interesting capital in commercial aviation. This is an extremely knotty problem for the reason that it takes considerable capital to demonstrate the possibilities of a fair return on an investment of this character. Furthermore, I believe that not even aviation's staunchest supporters will claim that commercial aviation can be made to pay from the start. There is bound to be a period of development and experimentation that will more than absorb all possible profits. Again, what protection is there for the pioneer? If it were possible for the Government to grant exclusive franchises over certain air-routes for extensive periods, there might be a chance of inducing capitalists to invest; but I hesitate even to suggest the possibility of such franchises. Without such protection the pioneers would be forced to develop at considerable expense the most suitable flying equipment, schedules, routes and many details of organization that competitors could duplicate a few years later, driving the pioneers, burdened with the heavy expenditures incurred during the development stage, out of business.

I have attempted to present the status of commercial aviation today in the United States and propose to consider now the general trend of plane and engine design.

Trend of Design

For the purposes of this discussion we will consider in turn the three principal elements of the plane, the wing truss, fuselage and powerplant. In reviewing design tendencies in these fields I propose to cover the ground rather broadly as it is the object of this paper to bring out some constructive ideas that may assist in some slight measure in the advance of commercial aviation in this Country, rather than to get into a discussion of the relative merits of different designs. At the outset let us decide what type of airplane it behooves us to consider in this connection. Of the two types, water and land planes, there is little question that the future of commercial aviation must rest chiefly with the latter.

There are some splendid but limited opportunities for the use of hydroairplanes and flying-boats along our coast and between our Lake cities, and these fields are being gradually developed. The chief advantage of the water machine rests with its ability to "land" on any suitable body of water, weather conditions being reasonable. The need for expensive landing-fields is obviated and the initial investment thereby reduced. On the other hand, the routes are necessarily restricted and the machines themselves are far less efficient than land planes due to the high parasitic resistance of the hull and pontoons. It is indeed a question whether land machines fitted with emergency flotation-gear are not preferable over water routes of not too great length; it may be remembered that all air transport across the English Channel is by land machines. Assuming, therefore, that our discussion is to be confined to land machines, what particular type should we consider as best meeting the immediate needs of commercial aviation? There are many conflicting aspects of this phase of the problem. From an operating standpoint we are justified in expecting that the lowest operating cost would be associated with rather large planes, having ample capacity for passengers and freight. On the other hand, the initial investment and risk of damage would be proportionately greater with the larger units. All things considered, I believe we can safely say that the smallest plane that can be economically operated and be made to pay in commercial service would have a capacity of about 10 passengers or approximately 2000 lb. of freight. While this may sound like more or less of an arbitrary conclusion, it is based largely on present-day knowledge of structural limitations.

Considering now the wing truss for such a machine, there are two general types of construction to choose from. The first is the older and conventional, externally braced, trussed type, generally of biplane form; the second is the more recent, internally braced, thick wing-section, generally associated with monoplane design. This latter type lends itself particularly well to all-metal construction. From the commercial standpoint there are many points in favor of the internally braced wing, chief of which are the decrease in maintenance and inspection costs, improved economy in operation due to improved aerodynamic performance and the ability to make quick repairs by replacing the entire unit. The possibility of storing fuel and freight in the wing is quite alluring, and the improved vision for the passengers must not be overlooked. All things considered, it is evident that the internally braced wing presents overwhelming advantages for commercial planes. Just what material should be employed in the wing structure is a question of less import. An all-metal structure offers theoretical advantages from an upkeep standpoint. On the other hand, it is necessarily more rigid than a built-up wood construction reinforced with suitable tension-wires, and the resistance to fatiguing stresses induced in the metal wing by the fine vibrations transmitted from engine and propeller is questionable. If ultimately crystallization is to set in and sudden fracture take place, the consequences might be exceedingly grave. Summing up, it is evident that the internally braced wing is exceptionally well suited for commercial planes, but that all-metal wings of this type will continue to be looked on with suspicion until a large amount of experience shall have shown that they have practically an unlimited life and cannot be said to depreciate with use.

All things considered, I think it is a fair statement to make that the question of a specific wing-truss is not a material factor in the advance of commercial aviation. In other words, all present standard forms of construction can be considered satisfactory for commercial purposes, although, as remarked above, some of the newer constructions will undoubtedly effect savings in upkeep and hence bring the air-transportation era one step closer.

Taking up the question of fuselage construction, we recognize that there exists a general tendency in design toward more rugged construction, considerable attention being paid to securing reduced cost of manufacture and upkeep. The built-up veneer trussed type appears to be giving way to the all-steel truss type. One form of construction which seems to be excellent is that in which the fuselage is constituted of steel-tubing units welded-up in jigs and reinforced by tension-wires. The question of fuselage design is dominated by the need of an accessible powerplant mounting. In the present stage of aircraft-engine development it is necessary to overhaul the engine rather frequently, that is, every 200 to 300 hr. at least, and it is therefore important to be able to remove it in a minimum length of time so as not to tie up the plane for an undue period. In fact, the ideal scheme seems to be to have a spare powerplant available at all times for substitution. The steel fuselage lends itself particularly well to the accomplishment of this very desirable feature of accessibility and this can be carried out in a cleancut manner by extending the upper and lower longerons on each side so as to meet at the front of the engine support. In the older forms of veneer-covered-truss fuselages or with the so-called monocoque construction the engine was generally extremely inaccessible, at any rate from both sides.

Regarding the general cabin design for the passenger compartment the requirements in the matter of comfort, good vision and ventilation seem obvious. Later we may expect to see serious consideration given to attempting great structural strength in the cabin structure to protect the passengers as much as possible in case of a crash. This would follow the precedent set in railway Pullman-car construction but, of course, the problem in the case of aircraft is rendered far more difficult by minimum-weight requirements. Easy access to the cabin from the ground is naturally desirable from the passenger's standpoint and in most enclosed designs this has been carefully studied.

There is apparently considerable difficulty in arriving at the best location for the pilot. The first requirement is, of course, the best possible vision not only for landing but also while in the air; the pilot should be able to see in all directions. In the event of the plane nosing over, the pilot should be in such a position as to be protected from the engine, gasoline tanks or other heavy units. It is undoubtedly desirable, although not essential, that the pilot be able to obtain access to the passengers' compartment, and there should be also accommodation for a mechanic or relief pilot. The pilot's cockpit should be in such a place as to simplify both the plane and the engine controls, making them as direct as possible. Of course, in the case of a multi-engine plane in which the engines are carried out on the wings a suitable position for the pilot is readily found in the forward part of the fuselage, but with the single-engine plane some other location must be found. In a very recent design the pilot is placed alongside of the engine; this appears to have some advantages.

I have not considered the tail-skid or landing-gear separately but these very important elements of the design need much study and development to reduce the present high cost of upkeep. There appears to be a

definite need for some shock-absorbing means in both the landing-gear and the tail-skid. By shock-absorber I mean a device to actually absorb the shock and not store it momentarily as is done with springs or elastic rubber suspensions.

The location of the gasoline tanks is another problem that has not reached a final solution, in my estimation. There are several factors to be taken into consideration, such as the method of gasoline feed, that is, pressure or gravity, the capacity of the tanks, and effect of the full or empty tank on the respective balance of the airplane, remoteness from any fire-producing element and accessibility for filling. The most important consideration of all is undoubtedly that of fire prevention and on this score a location out on the wings is preferable.

Scanning the question of the powerplant for a typical commercial airplane, the first requirements we encounter are reliability and accessibility. Next in order come economy in operation and low initial cost. In the matter of reliability of the engine itself, a high state of development has been reached, although the powerplant as a whole has not advanced in a corresponding degree due to the lack of coordination of engine and plane design and the incomplete working out of important installation details. This handicap is being overcome rapidly as engine designers become more familiar with actual airplane operating conditions and plane designers appreciate more and more the installation and operating requirements of the powerplant. Basically, then, we find that there exist several well-known makes of engine that are highly reliable. The next step is to produce reliable engines that will lend themselves to simple installation and easy maintenance. This phase of the situation is well understood by all airplane-engine designers, as is shown by some typical examples of modern powerplants referred to later. It should of course be borne in mind that the engine designer must lead the way, since the plane must be built around the engine to form an harmonious combination. The problem therefore requires the closest possible cooperation between the engine and the plane designer. Both should acquire extensive flying experience to obtain the best possible insight into operation and maintenance problems.

Powerplant Requirements

Carburetion is undoubtedly the foremost of the concrete examples of powerplant requirements, since the location of the carbureter has considerable influence on the design of the engine and affects the design of the plane. The ideal gasoline system seems to be gravity-feed, owing to its inherent simplicity and consequent reliability. Assuming a fairly high location for the gasoline tanks, it is easy by placing the carbureter beneath the engine to obtain a very efficient gravity feed with ample head under all normal flying conditions. There are several other advantages in thus locating the carbureter, including the ability to carry the air-intake out through the lower cowling, eliminating any possible danger of fire due to engine backfiring. It is, of course, important to carry gasoline-overflow pipes or vent connections into the air-intake so that in case of flooding the gasoline will drip harmlessly from the air-intake. It should be remembered that in the case of the conventional single-engined tractor powerplant installation the engine is most accessible from beneath or from either side, whereas in the case of the automobile engine the sides and top are easiest to work on.

Next after the carbureter comes the lubricating system in importance as regards accessibility requirements. This applies to such important elements as the oil-pump itself, pressure-regulating valve and oil-screen, all of which should be readily accessible in the completed plane. It appears to be good practice to operate the engine with a dry sump; in which case an external oil-tank, which serves also as an oil-cooler, must be provided in proximity to the engine.

The water-pump is usually driven from a vertical shaft at the rear end of the engine and can thus be easily inspected from underneath. The ignition system, which should invariably be supplied in duplicate whether it be in the form of magnetos or battery distributors, is best arranged at the rear end transversely with respect to the crankshaft so that adjustments or inspections can be made from either side. The location of the spark-plugs is more or less determined by the general type of engine construction, but one set at least should be readily accessible from either side; in the case of a V-engine the other set can be located conveniently in the V if there is plenty of space available. In this case a suitable sliding door should be provided in the upper part of the cowling so that these spark-plugs can be reached without removing the cowling as a whole.

The radiator should be considered as part of the powerplant, since its design is tied up with the characteristics of the particular engine employed. There are several alternative locations for the radiator, but the so-called "nose" radiator directly behind the propeller appears to have overwhelming advantages for commercial purposes. Although this is by no means the most efficient position for a radiator so far as its cooling ability is concerned, it appears that for convenience in connecting to the engine and for general accessibility it offers sufficient advantages to warrant its general adoption for commercial planes. The radiator should have ample area and a liberal expansion-tank, together with an efficient shutter equipment. It is important that the shutters fit well when closed; and it is preferable that they be balanced and streamlined so as to offer no difficulty in maintaining any desired adjustment in flight. Apparently it is good practice to mount the engine on wood bearers. These can be extended to carry a suitable stamping that in turn supports the radiator. These same timbers can also be extended through the engine firewall to support the gasoline tank if such a location is suitable.

There are a great many very important details in connection with the installation of the engine and its controls; these deserve the closest possible attention. Gasoline, water and oil lines must all be worked out with a view to their withstanding vibration, but at the same time the use of rubber hose for either water or oil connections should be limited as far as possible, suitable metallic linings being employed to prevent any possible obstruction by rubber particles disintegrated by the action of the gasoline or oil. Needless to say, in every case where rubber connections are used for gasoline or oil, strainers should be provided in a very accessible location on the engine side of the joint. Engine controls, such as spark, throttle, mixture and radiator-shutter, should all be carried out in a mechanical and workmanlike manner. The use of flexible cable for such work is not to be recommended. The construction should take the form of tubular connecting-rods combining lightness with rigidity, bell-cranks and levers connected with suitable clevises, and the proper number of bearings suitably arranged to carry the various shafts with the least cramping tendency. It is desirable to carry out a mechanical, positive construction such as that outlined above in all the flying controls; that is, in an ideal system no flexible cable

would be used for operating ailerons, rudder, elevator or adjustable stabilizer if used. The propeller also can be considered an important part of the powerplant since in its design the characteristics of the engine must be taken into consideration, although the airplane itself exerts a considerable influence on the propeller design.

The question of starting means for airplane engines has been frequently discussed, with various results. The electric starter is apparently the only available successful mechanical starter attached to the engine. Its use, naturally, necessitates the employment of a storage battery. The battery involves some objections from the standpoints of maintenance, weight and injury to metals or wood in its vicinity. All things considered, the use of a mechanical engine starter on a commercial airplane is open to question, since with suitable priming devices, handcrank magneto, etc., the engine can be started very readily by hand. Experience alone will show whether the advantages of the electric starter are sufficient to overcome such disadvantages as I have cited.

I have purposely refrained from discussing air-cooled engines or other types of powerplant, since the purpose of this paper is not so much to point out future possibilities as to present the status of commercial aviation today, placing particular stress on retarding influences. I believe, in general, that there are several types of modern high-grade power-plant from which to choose and that the lack of a suitable powerplant cannot be said to be obstructing the advance of commercial aviation, although I look forward to constant improvement of the engines in the direction of greater reliability and economy and decreased cost of construction with not very much reduction in weight.

Essentials of Air Transportation

Having considered the question of commercial aviation from different angles, we are in a position to specify some of the more important steps necessary in the further development of air transportation. As I have stated, this paper is necessarily too limited in scope to include a discussion of a multitude of detail refinements, each of which will contribute its quota to commercial aeronautics. I might cite navigating instruments, which are the basis of a large field for development, and wireless direction-finding, wireless telephone and night-flying equipment. There is great need for propellers of moderate cost that will withstand the attacks of rain or sleet; variable-pitch and reversible propellers are gradually being evolved from the experimental stage. Considerable work is being done on wings having variable camber or variable surface. These few examples of development activities in the various branches of airplane design indicate the ramifications of the art and the hopelessness of attempting to present a complete picture of the situation. I have tried to pick the high lights and draw some general conclusions from them.

Summing up, I have enumerated the following four points which may be said to represent the essential and fundamental requirements for the further progress of commercial aviation:

(1) A system of landing-fields must be determined upon and put into service throughout the country as rapidly as possible. Although at the outset air traffic will be extremely limited, unless these landing-fields are available in advance, I can see no hope for the rapid extension of commercial air-transportation. I am glad to note that the daily press is giving its support to the movement to construct municipal landing-fields throughout the country.

(2) The aid of Government experimental stations should be enlisted in the task of eliminating so far as possible such danger factors as are inherent in the present airplane designs. I have in mind chiefly the matter of stalling which is referred to at considerable length above. A partial solution of this problem may lie in having an intermediate stop for each set of flying controls, that would allow sufficient range for normal flying, although perhaps not sufficient just previous to landing or when taxiing. A Federal system of inspection, coupled with suitable short-period licenses and stringent regulations governing important elements of aircraft design, would undoubtedly assist in preventing a certain percentage of avoidable accidents.

(3) Government patronage of air-transportation companies in the form of mail contracts, which might be made somewhat more liberal than the present ones by charging a very nominal extra postage. I am fully aware that at the outset of the Air Mail Service this procedure was not successful in attracting patronage, but I believe this was due to an excessive surcharge. A preferable course might be to limit the weight to one-half that allowed by rail route for the same postage. I have touched upon the possibility of establishing Government franchises over specific air-routes. While I recognize the crudity of the suggestion, some means might be devised of restricting the number of Federal licenses to be issued to air-transportation companies to operate between any two points for a definite period. Such licenses could have qualifying clauses stipulating a minimum number of trips or in some other way insure adequate service.

(4) Both plane and engine development along utilitarian lines should be concentrated on by our Government experimental stations. In the final analysis, even in time of war, reliability and ease of maintenance are important factors. In the past we have been paying almost exclusive attention to the performance of our military planes, which was, of course, a laudable endeavor. Nevertheless, it appears to be equally important to encourage development work that would be more applicable to peacetime flying, recognizing that the fruit of this would be extremely valuable in the evolution of commercial aeronautics, which in turn would help build up what would be in effect a Reserve Air Force. In other words, neither extremely high speed nor rapid climbing to excessive altitudes represents characteristics of particular value to commercial air-transportation, whereas increased economy in operation, slower depreciation and decreased upkeep expense are all vital factors in this connection.

Viscosity and Friction

By WINSLOW H. HERSCHEL[1]

ANNUAL MEETING PAPER — *Illustrated with* CHARTS

THE author divides the study of lubrication into different regimes in which different properties of the lubricant have the controlling influence and discusses at length viscosity effect in the complete-film-lubrication regime, including comment on the properties of lubricants, units for viscosity measurement, absolute viscosity relation to the readings of instruments ordinarily used and mathematical analysis, with reference to data that are presented in tabular and chart form.

Viscosity estimation at one temperature from the observed viscosity at another temperature is then treated in a somewhat similar manner, inclusive of discussion bearing on complete film lubrication, as are the subjects of journal friction and viscosity in which the mathematical analysis is continued, and friction tests are described briefly, copious specific references being given.

Consideration is given to the transition point, the relation between the different factors at the transition point and incomplete film lubrication and the oiliness of lubricating oils, the last including a description of Bureau of Standards tests.

A lengthy discussion of the differences in oiliness of different lubricants shown by laboratory and service tests follows, many references to tests and testing machines being cited and quotations made from reports.

Ten specific desirable features of oil-friction testing-machines are enumerated and commented upon in the light of previous experiences that are cited, and nine specific conclusions regarding viscosity and friction are stated.

THE study of lubrication is made more difficult by the fact that there are different regimes in which different properties of the lubricant have the controlling influence. At the highest speeds and lowest pressures the friction is nearly constant under widely varying conditions. At lower speeds the viscosity of the lubricant and the kind of material constituting the rubbing surfaces have a marked effect; and at the lowest speeds and highest pressures another property of the lubricant, which can be called oiliness, has the predominant influence. Frequently, only two regimes are considered; that of complete film lubrication where the viscosity has the greatest effect, and that of incomplete film lubrication where the oiliness becomes of major importance. The transition point, where the friction is at a minimum, comes within the former regime. The influence of bearing metals is evident with incomplete film lubrication, and in the greater part of the regime of complete film lubrication.

In selecting a lubricant the properties that need to be considered can be divided into two classes; properties indicating that it is suitable for the purpose at hand, and those giving assurance that it will be reasonably lasting in use. It is not the purpose of this paper to consider the question of the deterioration of oils, but merely the above-mentioned properties of new oils that indicate suitability at least for short-time use. If all the changes of the lubricant with time, by evaporation, oxidation or otherwise are disregarded, the only remaining properties that determine the friction are viscosity and oiliness.

TABLE 1—UNITS OF VISCOSITY

1 dyne-sec. per sq. cm.	= 1 poise
1 lb-min. per sq. in.	= 4.137×10^6 poises
1 kg-sec. per sq. meter	= 98.07 poises
1 poundal-sec. per sq. in.	= 2,143 poises

VISCOSITY EFFECT IN THE COMPLETE-FILM-LUBRICATION REGIME

The instrument most generally used for determining the viscosity of lubricating oils by oil refiners in the United States is the Saybolt universal viscosimeter.[2] Its adoption, together with the standard temperatures of 100, 130 and 210 deg. fahr. (37.8, 54.4 and 98.9 deg. cent.), reduced the confusion and inaccuracy resulting from the use of viscosimeters of various types at different temperatures. Although conversions can be made from one instrument to another, there is no general agreement in regard to the conversion factors.

When a comparison is made between viscosity and friction it is necessary to express viscosity in some unit that is independent of the instrument used for measuring the viscosity, and equals or is proportional to the true or absolute viscosity. With the Saybolt instrument results are expressed in seconds, a unit that does not fulfill this requirement, although absolute viscosity can be calculated from Saybolt seconds by using a suitable equation.

The unit of absolute viscosity has been defined as the force that will move a unit area of plane surface at a unit speed relative to another parallel plane surface from which it is separated by a layer of the liquid of unit thickness. Most published data on viscosities of liquids are expressed in the centimeter-gram-second unit of absolute viscosity, known as the poise, and it will therefore be used in this paper. Table 1 is convenient for

TABLE 2—LIQUIDS AND TEMPERATURES NECESSARY TO GIVE CERTAIN ABSOLUTE VISCOSITIES

Viscosity, poises	Liquid	Approximate Temperature, deg. fahr.	Approximate Temperature, deg. cent.
0.01	Water	68	20
0.05	Sucrose, 60 per cent	182	83
0.10	Sperm Oil	135	57
0.20	Sperm Oil	94	34
0.30	Olive Oil	112	44
0.40	Olive Oil	98	37
0.50	Olive Oil	87	31
0.75	Olive Oil	71	22
1.00	Olive Oil	60	16
5.00	Castor Oil	83	28
10.00	Castor Oil	68	20

[1] Associate physicist, Bureau of Standards, City of Washington.

[2] See Standards adopted in 1920 by the American Society for Testing Materials, p. 104; also, Tests and Testing Standards adopted by the National Petroleum Association, Sept. 22, 1920; also, Bureau of Mines Bulletin No. 5, containing the Report of Committee on Standardization of Petroleum Specifications, p. 28.

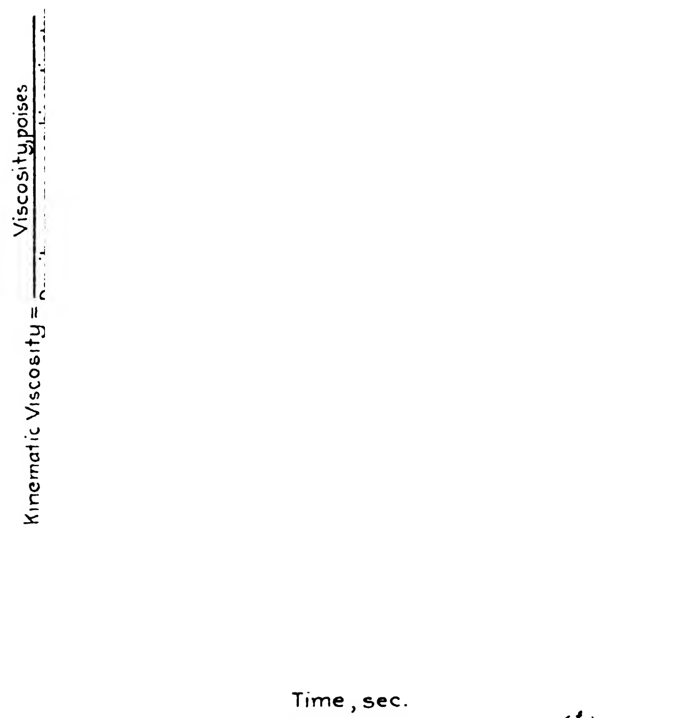


FIG. 1—CONVERSION DIAGRAM FOR VISCOSIMETER READINGS

comparison between different units that are sometimes encountered, while Table 2 has been compiled to give a concrete meaning to viscosities expressed in poises.

ABSOLUTE VISCOSITY RELATION TO THE READINGS OF INSTRUMENTS ORDINARILY USED

The Saybolt universal viscosimeter and most of the other commercial viscosimeters that are used with lubricating oils are of the efflux type and, if there is no turbulence, their readings can be converted into poises by the equation

$$V_k = At - (B/t) \qquad (1)$$

where

A = an instrumental constant
B = an instrumental constant
V_k = kinematic viscosity which is the quotient obtained by dividing the viscosity in poises by the density in grams per cubic centimeter
t = time of flow in seconds

The term in parenthesis in equation (1) is the kinetic energy correction

$$B/t = (Q\,m) \div (8\,\pi\,L\,t) \qquad (2)$$

where

B = an instrumental constant
L = effective length of the outlet tube, usually slightly in excess of the measured length; the difference is known as the Couette correction
m = a coefficient approximately equal to unity
Q = volume of flow in cubic centimeters in the time t
t = time of flow in seconds

If the flow is so slow that B/t is negligible in comparison with At, and the outlet tube is so long that the Couette correction can be neglected, then the viscosity can be calculated from the equation

$$V_k = At = (\pi\,g\,d^4\,Ht) \div (128\,Q\,L) \qquad (3)$$

where

A = an instrumental constant
d = diameter of the outlet tube
g = acceleration of gravity, or 981 cm. per sec. squared
H = average hydrostatic head above the bottom of the outlet tube, producing flow
L = effective length of the outlet tube
Q = volume of flow in the time t
t = time of flow in seconds
V_k = kinematic viscosity

Equation (3) does not apply to commercial viscosimeters, with the probable exception of the Barbey, because the outlet tubes are too short. On this account, and because the Couette and kinetic-energy corrections cannot be calculated on theoretical grounds, it is necessary to determine values of L and m, and hence of A and B, in equation (1), by the use of calibrating liquids of known viscosity. The viscosity of these liquids is measured by some suitable viscosimeter to which equation (3) applies. If L and m are determined in this way, the greatest error will be due to inaccuracy in the measurement of d.

Early investigators assumed that there would be no turbulence and equation (1) would apply, provided the value of K in equation (4) was less than 2000.

$$K = 4\,Q \div (\pi\,d\,t\,V_k) = v\,d/V_k \qquad (4)$$

where

d = diameter of outlet tube
K = a constant
Q = volume of flow in time t
t = time of flow in seconds
v = velocity of flow in centimeters per second
V_k = kinematic viscosity

While it is now known that K decreases with the length of outlet tube, the law of variation is not known. K has a value of 800 for the Saybolt universal viscosimeter, and therefore water cannot be used as a calibrating liquid for that instrument. This is unfortunate, because water is easily procurable and its viscosity is more accurately known than that of any other liquid. Values of A and B will vary with each individual instrument on account of unavoidable variations in dimensions. If, however, these constants are determined for a type of instrument for which standard dimensions with suitable tolerances have been adopted, the variations in the constants will not exceed a reasonable predetermined amount.

In making conversions between different types of viscosimeters it is convenient to write equation (1) in the form

$$t = C\,V_k(1 + \sqrt{[1 + (D/V_k^2)]}) \qquad (5)$$

where

$$C = 1 \div 2\,A$$
$$D = 4\,A\,B$$

The best available values of A, B, C and D are given in Table 3, for viscosimeters of normal or average

TABLE 3—INSTRUMENTAL CONSTANTS FOR VISCOSIMETERS

Instrument	A	B	C	D	Minimum Time, sec.
Saybolt Universal	0.0022000	1.800	227.30	0.01584	32
Saybolt Furol	0.0220000	2.030	22.73	0.17860	13
Engler	0.0014700	3.740	340.30	0.02196	56
Redwood No. 1	0.0026000	1.880	192.30	0.01952	30
Redwood No. 2 (Admiralty)	0.0239000	0.403	20.92	0.03857	5
Ubbelohde	0.0000868	1.440	57.60	0.04993	155

standard dimensions, together with the minimum time of flow to which the equations apply.

Table 3 has been used to calculate Fig. 1, the form of which is due to MacCoull[3] who, however, extended his curves to lower times of flow. With all except the Engler and Barbey viscosimeters, the results are usually reported in seconds. With the Engler viscosimeter, results are usually reported in Engler degrees, the values being obtained by dividing the time of flow by the water rate, or the time of flow for water at 68 deg. fahr. (20 deg. cent.), which varies from 50 to 52 sec. Since the viscosity is not proportional to the time of flow, a value in Engler degrees, which is only the ratio between times of flow, does not represent the ratio of the viscosity of the liquid tested to the viscosity of water. With the Barbey instrument, tests are run for 10 min. and results are reported as "fluidity," which is the flow in cubic centimeters per hour.

Viscosity Estimation at One Temperature from Observed Viscosity at Another Temperature

It is known that oils grow less viscous or "thin out" as the temperature increases, but the exact law of variation is unknown. If it is desired to estimate the viscosity of an oil at one temperature from the observed viscosity at another, a convenient method is to assume that the logarithmic viscosity-temperature graphs are straight and meet at a point. This assumption is sufficiently accurate for most practical purposes if the fahrenheit scale is used, and if fatty oils, steam-cylinder oils, oils of lower viscosity than spindle oils and imperfectly refined oils such as fuel oils, are excluded. It is also necessary that all oils on a diagram should be from one crude, as different crudes show different points of intersection.

Fig. 2 shows such a logarithmic viscosity-temperature diagram as has been referred to, from tests on different fractions of the same naphthene-base oil. It will be seen that, within the limits of accuracy of viscosity determinations, these oils give straight graphs and, since they are all of the same base, the graphs within a certain range of viscosity meet at a point. The point of intersection for oils of any other crude could be obtained in a similar manner, but if more accurate information is not available, the points of intersection can be assumed as given in Table 4.

TABLE 4—POINTS OF INTERSECTION OF LOGARITHMIC VISCOSITY-TEMPERATURE GRAPHS

Base of Crude Oil	Viscosity, poises	Temperature deg. fahr.
Paraffin	0.0038	589
Naphthene	0.0076	371

None of the tests used in finding the values given in Table 4 were run at temperatures over 212 deg. fahr. (100 deg. cent.) or below 60 deg. fahr. (15.6 deg. cent.), and extrapolation beyond these limits would of course be hazardous.

In estimating viscosities, one point on the diagram is located by the known viscosity of the oil in question at a given temperature. The point of intersection is then located and the desired viscosity is read from the straight line connecting these two points. By combining the methods of converting from readings of one viscosimeter to another, and of estimating the change of viscosity with the temperature, conversions can be made from one type of instrument at one temperature to another type at another temperature, although Fig. 1, alone, serves merely for comparisons between tests at the same temperature. But estimates of the change of viscosity with the temperature must always be dangerous, as impurities may be present in the oil and change the temperature coefficient of the viscosity.

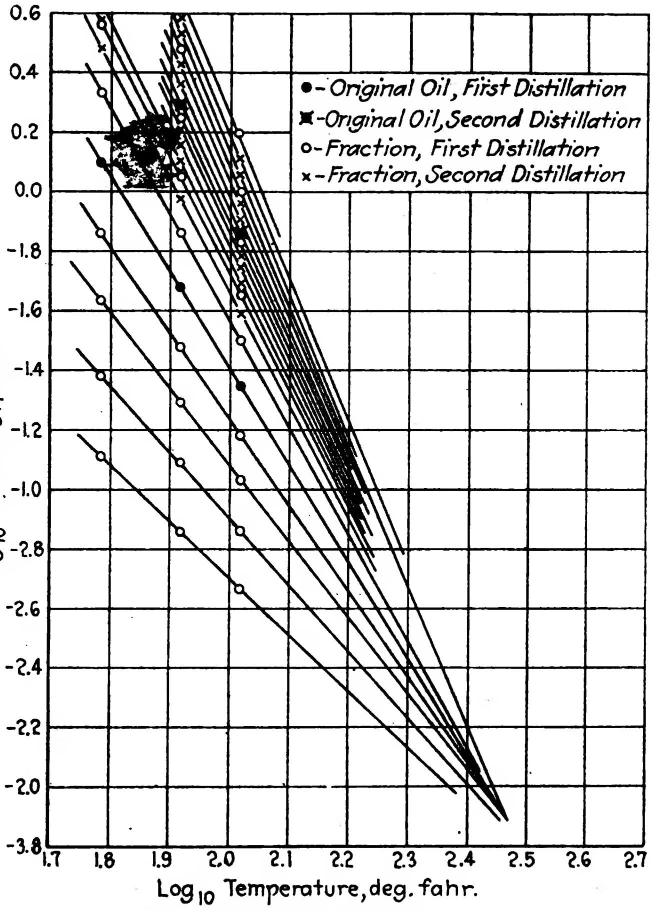


FIG. 2—LOGARITHM VISCOSITY-TEMPERATURE DIAGRAM BASED ON TESTS OF DIFFERENT FRACTIONS OF THE SAME NAPHTHENE-BASE OIL

When it is desired to know the viscosity of an oil at the temperature of a bearing, as in friction tests, the viscosity determinations should be made at several temperatures within the range of the probable bearing temperature. The logarithmic viscosity-temperature diagram, together with the point of intersection, can then be used as a check on the accuracy of the viscosity determinations, and as a means of enabling the interpolation to be made on a straight rather than on a curved line.

Every mathematical treatment of the subject of lubrication is based upon the assumption that viscosity is the only property of the lubricant that has an influence upon the friction, and that the degree of smoothness or the material of the bearing and the journal are also without influence. While many friction tests have been made and published, there are very few that give sufficient data to check the accuracy of proposed formulas. All experimenters have observed the pressure, the speed and the coefficient of friction, but few have paid attention to measurements of the viscosity and of the clearance in the bearing, which are equally important. Reference[4] is made to some of the few cases where film thickness has been measured.

It is known that a journal is not concentric with the

[3] See *Lubrication*, May, 1921.

[4] See *Transactions of American Society of Mechanical Engineers*, vol. 27, p. 423; *Archiv für Electrotechnik*, vol. 8, p. 364; and *Journal of the American Society of Mechanical Engineers*, vol. 39, p. 320.

bearing when running at moderate speeds; but, for the sake of simplicity, it will be assumed at first that it is concentric so that the film thickness, Δ, is one-half the difference in diameters of bearing and journal. Then, from the definition of viscosity, the turning moment due to fluid friction would be, for a journal completely surrounded by the bearing,

$$M = [\mu\, d\, (\pi\, d\, l)\, V] \div 2\, \Delta \qquad (6)$$

where

d = diameter of the journal
l = length of the journal
M = turning moment due to fluid friction
μ = viscosity in poises
$\pi\, d\, l$ = area of the rubbing surfaces
V = speed of rubbing

In expressing the results of friction tests it is customary to make use of the coefficient of friction, f, a purely arbitrary value obtained by dividing the tangential force by the total load P. Thus the turning moment of a journal having a diameter of d is

$$M = \tfrac{1}{2}\, f\, d\, P \qquad (7)$$

Combining equations (6) and (7), we get

$$f = [\mu\, (\pi\, d\, l)\, V] \div \Delta\, P \qquad (8)$$

According to equation (8) friction is proportional to the speed. At certain low speeds this is true,[5] at moderate speeds friction is approximately proportional to the square root of the speed, and at very high speeds Lasche[6] found that under the conditions of his tests f was almost independent of the pressure, the speed, the temperature and the bearing metal.

The proportionality between the friction and the viscosity is shown by Tower's[7] experiments, made on a bearing which extended about one-half way around the journal. In tests with lard oil at various temperatures, the highest friction was obtained at 60 deg. fahr. (15.6 deg. cent.). Calling the friction and viscosity 100 at this temperature, Table 5, calculated from Tower's data, shows the relative values of the coefficients of friction and of the viscosity of lard oil at the other temperatures.

It will be seen that there is a considerable variation in the change of viscosity with the temperature, according to different experimenters, probably due in part to differences in the viscosimeters employed. While the change of friction with the temperature is not exactly the same at all speeds, the average values for friction lie between those of Goodman and the Bureau of Standards for viscosity. Thus, as indicated by equation (8), at least under certain conditions, friction is proportional to viscosity. That friction is inversely proportional to the film thickness has been shown by Heimann.[8]

There is nothing in equation (8) to indicate that f would not continue indefinitely to decrease as the pressure increased but, in reality, there is a change in the regime at very high pressures or very low speeds at what is called the transition point; this is considered later. Thurston's[9] tests with varying pressure gave indications not only of a transition point but also of the influence upon friction of a change in the material of the rubbing surfaces. He found that the coefficient of friction was less at a pressure of 500 lb. per sq. in. (35.0 kg. per sq. cm.) than for either 250 or 750 lb. per sq. in. (17.5 or 52.5 kg. per sq. cm.), and less for steel journals in brass bearings than for cast-iron journals in steel bearings. It is evident that these results cannot be explained by equation (8).

Friction Testing of Bearing Metals

It appears from the results of Thurston and others that, under certain conditions, a friction machine can be used to determine the relative friction-reducing properties of different alloys. As the effect of different bearing metals upon the friction can be noted above as well as below the transition point, some friction tests of these metals will be considered briefly at this point.

G. H. Clamer,[10] who used a Cornell friction machine, observed the friction, the running temperature and the loss of metal by wear, obtained by weighing the bearing metal before and after test. To get sufficient wear he ran each test at a speed of 525 r.p.m. for 10,000 revolutions, or about 3 hr. Neither the rise in the temperature nor the wear shows any regular relation to the friction. With a friction of 13.0 to 18.5 lb. (5.9 to 8.4 kg.) and with a pressure of 1000 lb. per sq. in. (70.3 kg. per sq. cm.), as stated by Clamer, and assuming one test-bar, it can be calculated that the load on the bar was 1750 lb. (794 kg.) and that the coefficient of friction varied from 0.00743 to 0.01057. The Cornell machine was at one time built to hold two test-bars, but Clamer does not state his area of rubbing surface, so that the number of test-bars is uncertain.

While Clamer's method of measuring wear is perhaps a usual one, there is no satisfactory method according to Goodman.[11] After having tried measuring the thickness by a Whitworth measuring machine, weighing the bearing in a chemical balance and measuring with a spherometer, arranging the legs on portions of the bearing not exposed to wear, he concludes

> All the methods failed to show any appreciable wear after a month's run under a pressure of 500 lb. per sq. in. (35.1 kg. per sq. cm.). These tests were made of course after the bearing was properly bedded down

If Goodman's statement is accepted as applying to Clamer's work, the conclusion is inevitable that the wear noted by Clamer was due to inaccuracy in the fit of bearing and journal, and that the wear had no significance except perhaps as an indication of the ease or difficulty with which a given bearing metal can be fitted to the journal. Goodman states that it would take a month or more to secure a perfect surface by wear, and that he loaded the bearing just beyond the elastic limit of the metal to expedite matters, and left this load on for about 15 min. Even after this treatment, a week's run in the testing machine was necessary before he considered the bearing had bedded itself perfectly. If preparation of this kind is necessary, it is small wonder that other experimenters have noted considerable wear of bearings. It might be objected that the quality of the bearing metal was changed so that Goodman's tests do not show the friction quality of his original samples. While it thus remains a problem in testing bearing metals how to make a perfect fit by other means, the above objection would not apply to tests of lubricants.

The Transition Point

It has been pointed out previously that equation (8) gives no indication of more than one regime of lubrication, or of the change at the transition point, in the rela-

[5] See *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 46, p. 1890.
[6] See *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 46, p. 1346; *Journal of the American Society of Naval Engineers*, vol. 11, No. 2; and *Zeitschrift für Mathematik und Physik*, vol. 50, p. 97.
[7] See *Proceedings of the Institution of Mechanical Engineers*, 1883, p. 651.
[8] See *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 49, p. 1165.
[9] See Friction and Lost Work, by R. H. Thurston, p. 297.
[10] See *Journal of the Franklin Institute*, vol. 156, pp. 61 and 70.
[11] See *Proceedings of the Institution of Civil Engineers*, vol. 189, part 3, p. 128.

tion between the different factors that determine the friction. Yet that such a change does occur has been shown both by experiment and by calculations based upon the laws of hydrodynamics.

Sommerfeld made a very thorough investigation of the hydrodynamics of the lubrication of a journal completely surrounded by the bearing. There are too few tests available with sufficiently complete data to check his formulas in all details, but certain points are in agreement with the tests. His equation for lubrication above the transition point approaches equation (8) as the speed increases and the journal becomes more and more nearly concentric with the bearing. Below the transition point, the friction increases as the speed decreases; so, the transition point is the point of minimum friction. Sommerfeld gives a theoretical equation for conditions at the transition point which can be written

$$\mu = (50\, p/\pi^2 n) \times (\Delta/d)^2 \qquad (9)$$

where

d = diameter of the journal
l = length of the journal
μ = viscosity in poises
n = speed of the journal in revolutions per minute
p = pressure on the bearing

Viscosities are usually given in poises, or in times of flow from which the viscosity in poises can be calculated by the equations already given. If the viscosity is expressed in poises, p must be taken in dynes per square centimeter, or 69,000 times the pressure in pounds per square inch but d and Δ can be taken in any convenient unit. If p is known in pounds per square inch, it might be convenient to use the equation,

$$\mu = (350{,}000\, p/n) \times (\Delta/d)^2 \qquad (10)$$

where

d = diameter of the journal
Δ = thickness of lubricating film
μ = viscosity in poises
n = speed of the journal in revolutions per minute
p = pressure on the bearing

The tests of Stribeck show that, with a given viscosity, the ratio p/n is a constant in accordance with equation (9). Using a viscosity of 1.90 poise, calculated from his data and the constants of Table 3 for the Engler viscosimeter, the clearance as calculated from equation (9) would be 0.0117 cm. (0.0046 in.). This is roughly checked by Sommerfeld's[12] value of 0.0130 cm. (0.0051 in.), presumably calculated from a different viscosity obtained by the incorrect equation of Ubbelohde for the Engler viscosimeter. Sommerfeld also obtains a value of 0.020 cm. (0.0079 in.) from the tests of Biel[13] and remarks that, although the actual clearances are not known, they were doubtless of the same order of magnitude. From the above value of 0.0117 cm. (0.0046 in.) from Stribeck's tests, and Sommerfeld's equation

$$f = 1.886\, \Delta/d \qquad (11)$$

the coefficient of friction at the transition point would be 0.00306. This is in fair agreement with Stribeck's experimentally determined values of 0.0035 to 0.0039.

To show the very low viscosities theoretically required with light loads, high speeds and small clearances, equation (9) has been applied to the case of a steam turbine, assuming a pressure of 80 lb. per sq. in. (5.62 kg. per sq. cm.), a speed of 1800 r.p.m., and a ratio of $\Delta/d = 0.0005$. Then the viscosity would be 0.00389 poises, which is about that of water at the running temperature of turbine bearings.

The difference between the calculated viscosity and that actually employed does not indicate an error in the equation, nor mistaken practice. There is always the possibility that the pressure and temperature in the bearing will be increased above the normal values from imperfect alignment or other cause, thus necessitating a more viscous lubricant. The friction increases much more rapidly with a decrease of viscosity below the transition point than with an increase in viscosity above it; so, it is impracticable actually to use a lubricant having the viscosity of minimum friction at the nominal temperature of the bearing and higher viscosities are always used. The excess friction above that at the transition point is the price that must be paid for an adequate factor of safety against seizure.

Some evidence of the general correctness of Sommerfeld's equations is furnished by his report on the examination of 40 locomotives that always ran in the same direction. According to the older theory of Thurston, the point of nearest approach of the bearing and the journal, or point of greatest wear due to fluid friction, would be toward the "on" side from the line of pressure; that is, around the journal in a direction opposite to the direction of rotation. According to Sommerfeld, the point of greatest wear should be on the other side of the line of pressure. It is therefore of interest that of the 40 locomotives, 30 showed more wear on the "off" side of bearings, 7 showed more wear on the "on" side and 3 were doubtful. While a majority of the locomotives showed wear in accordance with Sommerfeld's calculations, it is doubtful whether the 10 exceptions indicate that there was incomplete film lubrication in those cases,

[12] See *Zeitschrift für Technische Physik*, 1921, p. 598.

[13] See *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 64, pp. 447 and 483.

TABLE 5—COMPARISON OF RELATIVE FRICTION WITH RELATIVE VISCOSITY; FROM DATA OF TOWER AND OTHERS

Temperature		Relative Friction, according to Tower, for Speeds of									Relative Viscosity according to		
deg. fahr.	deg. cent.	Ft. per min. Meters per sec.	105 0.53	157 0.80	209 1.06	262 1.33	314 1.60	366 1.86	419 2.13	471 2.39	Goodman[14]	Thurston[15]	Bureau of Standards[16]
120	48.9		41	35	34	34	34	34	34	35	39	23	27
110	43.3		44	38	38	37	38	39	40	41	45	28	32
100	37.8		49	44	44	43	45	46	48	49	54	33	38
90	32.2		58	51	51	50	53	55	57	64	62	43	47
80	26.7		68	62	61	61	64	66	69	72	73	55	59
70	21.1		81	77	78	77	79	82	84	85	84	71	76
60	15.6		100	100	100	100	100	100	100	100	100	100	100

[14] See Lubrication and Lubricants, by L. Archbutt and R. M. Deeley, p. 85.

[15] See Friction and Lost Work, by R. H. Thurston, p. 191.

[16] From tests with the Bingham viscosimeter which is described in Bureau of Standards Scientific Paper No. 298.

that there were some factors that Sommerfeld did not take into account or that there were errors in the observations of wear.

It is interesting to observe that Sommerfeld's equations indicate an increase in the friction at lower viscosities than at the transition point, without any assumption of metallic contact or of incomplete film lubrication. But hydrodynamic theory accounts for an increase of friction of only 6 per cent, while the actual increase is very much greater. Sommerfeld's equations are based on the assumption that the clearance space is entirely filled with the lubricant, a condition that he has shown does not exist at very low speeds. His equations are therefore not in error, but are inapplicable to the regime of incomplete film lubrication. The conclusions are that, with complete film lubrication, experiments agree with theory within the experimental error so far as the properties of the lubricant are concerned; but, with incomplete film lubrication, theory is of little help.

Incomplete Film Lubrication and the Oiliness of Lubricating Oils

With complete film lubrication, viscosity is the only property of the lubricant that needs to be considered. With incomplete film lubrication, the differences in friction with different lubricants under otherwise identical conditions cannot be accounted for by differences in viscosity. Therefore, it is necessary to consider some other property, or properties, of the lubricant. This property is only vaguely understood; it is not identified with any recognized physical or chemical constants and is known by a variety of names such as body, oiliness, greasiness and the like. I shall use the word oiliness and define it as the property that causes a difference in the friction when two lubricants of the same viscosity at the temperature of the oil film are used under identical conditions.

A long series of tests was made at the Bureau of Standards to determine the utility of a certain friction-testing machine for measuring the oiliness of lubricants. The machine is of a well known commercial type and was belt-driven. The load is applied by a spring to a bearing block above the horizontal journal, the friction between the block and the journal being weighed by a lever arm having a sliding weight. The journal has a diameter of 3.748 in. (9.500 cm.) and is 3.480 in. (8.840 cm.) long. The width of the bronze bearing block is 2.010 in. (5.100 cm.) so that the gross projected area of the rubbing surface is 6.995 sq. in. (45.000 sq. cm.), thus checking the value of 7.000 sq. in. given in the manufacturer's circular. The maximum pressure ordinarily used was 715 lb. per sq. in. (50 kg. per sq. cm.), while the minimum attainable speed was 43.00 ft. per min. (0.22 meters per sec.). The arc of contact of the bronze bearing block was 65 deg., or less than one-half the arc of 163 deg. with which Tower obtained complete film lubrication on an otherwise somewhat similar machine. In all series of tests the bottom of the journal dipped into a cup of oil. To guard, if possible, against roughening of the journal when seizure took place, a special bearing block of white metal, consisting mainly of lead, was used. This block had neither oil-hole nor oil-grooves, and although the bronze bearing was thus supplied, the oil-hole was not used.

As the temperature could not be controlled, it was necessary to vary the viscosity by dilution. For the first series of tests, three oils were selected; a mineral oil of paraffin base, a second oil of naphthene base, and cottonseed oil. All three were diluted with 300-deg. mineral seal oil. This viscosity of minimum friction was about 0.05 poise, but with most of the tests the friction was practically independent of viscosity. On this account, it seems improbable that the condition of complete film lubrication was ever fully attained, although tests were made on both sides of the transition point. No comparison with Sommerfeld's equations is possible because the bearing did not completely surround the journal. Since the mineral seal oil had a viscosity near that of the minimum friction, kerosene and finally gasoline were used as diluents to obtain still lower viscosities. The excessive discordance in the readings that was observed in tests at these very low viscosities was doubtless due in part to the evaporation of the diluent and the consequent change of the viscosity during a test.

In the second series of tests, a mineral oil was selected as a standard of comparison and re-tests were made on this sample from time to time to detect changes in the smoothness of the rubbing surfaces. At the German Materialprüfungsamt, rape-seed oil is used for this purpose as is thus described by Holde[17]

> The machine is controlled now and then by using refined rape-seed oil. The coefficient of friction must come out within an error of 10 per cent under similar conditions of experiment; if this is not the case the machine must be run under an average pressure of 50 to 70 kg. per sq. cm. until the normal condition is reestablished; this sometimes requires several weeks.

The last two words show that there is need of some quicker method of obtaining a rubbing surface of standard smoothness.

Among the lubricants tested in the second series, already mentioned, were sucrose and glycerine solutions and petroleum oils containing mica and graphite, but there was no indication of differences in the oiliness. The tests also failed to show any superiority of the fatty oils as compared with mineral oils. While Meyers[18] also failed to find any advantage from the admixture of solid lubricants, it should be pointed out that the reduction of friction in case of failure of the oil supply, as shown by Mabery,[19] might be of considerable practical advantage. He found that a friction-testing machine would run much longer, after the supply of liquid lubricant had been cut off. if the oil had contained graphite.

In another series of tests at the Bureau of Standards, a comparison was made between the white-metal bearing used in all previous tests and the bronze bearing furnished with the testing machine, the lubricants being in general the same as in the second series. It was found that the coefficient of friction was mostly between 0.006 and 0.008 for the white metal and averaged about 0.009 for the bronze bearing. In most cases tests with the two bearings were alternated, so that the higher friction of the bronze bearing could not have been due to an increased roughness of the journal. The white metal had a higher carrying power than the bronze bearing; that is, an oil of lower viscosity could be used with the former without excessive friction or seizure. To determine whether the difference in friction and in bearing power between the two bearings was due to a difference in the curvature or of the film thickness, careful measurements were made of both bearings, but no difference could be detected. Taken all together, the tests of the Bureau of Standards appeared to show the impossibility of detect-

[17] See The Examination of Hydrocarbon Oils, by D. Holde, translated by E. Müeller, p. 124.

[18] See *Journal of the American Society of Naval Engineers*, vol. 29, p. 698.

[19] See *Journal of the American Society of Mechanical Engineers*, vol. 32, p. 163.

ing differences in the oiliness, unless the pressure was greater than about 800 lb. per sq. in. (56.2 kg. per sq. cm.) or the speed less than about 40 ft. per min. (0.20 meters per sec.).

Differences in Oiliness of Different Lubricants Shown by Tests

While the Bureau of Standards friction-machine tests above described and many others have failed to show differences in the oiliness, it has often been indicated by simple means that such differences exist. Archbutt and Deeley[20] suggest the following test to show that glycerine is deficient in oiliness.

> When a glass surface is rubbed by a wet finger, care having been taken to remove all grease, the friction between the skin and the glass is very considerable. Even such a thick liquid as glycerine, when the rubbing movement is slow, fails to keep the surfaces apart and prevent the glass from feeling harsh. On the other hand, a little grease, fat or lubricating oil will remain as a fairly thick film between the surfaces and enable them to slip freely over each other, even at low speeds.

Another simple means for testing oiliness is by using a lubricant as a cutting oil. Any machinist will use lard oil, when possible, to cut a "clean" thread, and it can be considered that the superiority of lard oil is due to oiliness. This is a case of intense pressure, as with gearing, and high pressures tend to produce incomplete film lubrication and manifestations of differences in oiliness.

J. H. Hyde of the National Physical Laboratory,[21] has made tests with a gear-testing machine designed by F. W. Lanchester and illustrated in the 1920 Report of the Lubricants and Lubrication Inquiry Committee of the British Department of Scientific and Industrial Research.[22] The machine is described in the National Physical Laboratory Report substantially as follows

> The machine consists of a worm-gearbox supported on ball bearings in such a way as to rotate about two axes, one at right angles to the worm shaft and the other at right angles to the driven shaft. The efficiency of the gear was measured directly by observing the angle of the axis about which the box tended to rotate. This enabled the efficiency to be obtained with one observation instead of calculating it from the energy supplied and transmitted in the usual way. Arrangements were provided on the machine for altering the load on the gear, and the drive was by a gasoline engine hand-governed for the particular speed required.

Referring to this machine in a discussion before the Physical Society, Stanton[23] said

> It was found that the frictional resistance of the gear was at 40 deg. cent. (104 deg. fahr.) the same with castor oil as with trotter oil, although the viscosities of the two were at that temperature as 6 to 1.

Reference is made also to full reports on tests with this machine in the *Proceedings of the Physical Society of London*[24] and other English publications. There is, however, danger of comparing the friction in tests in which the viscosities are so widely different, because it is difficult to determine how much of the difference in friction is due to a difference in viscosity, and how much to a difference in oiliness. Most of the tests showed a marked viscosity of minimum friction or of maximum efficiency. Arranged in order of excellence, based on this point of maximum efficiency, the oils tested were castor, sperm, trotter or neats foot, rape seed, F.F.F. cylinder, Victory Red and Bayonne, the last three being mineral oils.

TABLE 6—STATIC COEFFICIENTS OF FRICTION OF VARIOUS OILS

Name of Oil	Classification	Static Coefficient of Friction: Mild Steel on Cast Iron	Static Coefficient of Friction: Mild Steel on Lead Bronze
H. B., Clock..........	Mineral	0.271	0.275
Bayonne..............	Mineral	0.213	0.234
Typewriter...........	Mineral	0.211	0.294
Victory Red..........	Mineral	0.196	0.246
F. F. F. Cylinder.....	Mineral	0.193	0.236
Manchester Spindle...	Mineral	0.183	0.262
Castor...............	Vegetable	0.183	0.159
Valvoline Cylinder....	Compounded	0.143	....
Sperm................	Animal	0.127	0.180
Trotter..............	Animal	0.123	0.152
Olive................	Vegetable	0.119	0.196
Rape-Seed............	Vegetable	0.119	0.136

R. M. Deeley made tests of static friction with a special machine of his own design, and found that the coefficient of friction is markedly less with fatty oils than with mineral oils of the same viscosity. His friction machine, which is illustrated[25] in the 1920 Report of the Lubricants and Lubrication Inquiry Committee of the British Department of Scientific and Industrial Research, is thus described

> The experiments were made with a small hand-driven machine. Three pegs, each 5/32 in. (4 mm.) in diameter, rested upon the flat surface of a disc of metal that could be rotated slowly. These pegs were secured, concentrically, to an upper disc that could be weighted as desired and actuated a spindle to which a spiral spring and recording finger were attached. When the lower disc was rotated, the pegs were carried with it by the friction until the surfaces slipped, owing to the stress on the spring, and the finger gave the value of the frictional resistance.

Table 6 gives the results of Deeley's tests. These apparently were made at room temperature.

The objection to Deeley's machine, as well as to gear machines, appears to be that the pressure cannot be measured because the area of contact is uncertain and apt to vary from wear. There is also no provision for controlling the temperature with this machine.

L. Archbutt in referring to his tests[26] with a Thurston

TABLE 7—EFFECT OF FATTY ACID UPON COEFFICIENT OF FRICTION

Test No.	Mineral Oil, per cent	Fatty Acid from Rape-Seed Oil, per cent	Coefficient of Friction
1	100.0	0.0	0.0066
2	99.5	0.5	0.0049
3	99.0	1.0	0.0045
4	98.0	2.0	0.0042
5	100.0	0.0	0.0066

[20] See Lubrication and Lubricants, by L. Archbutt and R. M. Deeley, p. 31.

[21] See Report of National Physical Laboratory for 1912, p. 100.

[22] See Report of the Lubricants and Lubrication Inquiry Committee, Department of Scientific and Industrial Research, London, for 1920, p. 50.

[23] See *Engineering*, vol. 108, pp. 755 and 758.

[24] See *Proceedings of the Physical Society of London*, vol. 32, part 2, p. 5S; and Report of the Lubricants and Lubrication Inquiry Committee, Department of Scientific and Industrial Research, London, for 1920, pp. 50 to 79.

[25] See Report of the Lubricants and Lubrication Inquiry Committee, Department of Scientific and Industrial Research, London, for 1920, p. 102.

[26] See *Journal of the Society of Chemical Industry* (London), vol. 39, pp. 51 to 60T.

machine has shown, in his discussion of the paper by Wells and Southcombe, that differences in oiliness can be shown by tests at moderate pressures, at slow speeds, without going to the extreme case of zero speed. The observations stated in Table 7 were made on a Thurston friction machine without stopping the machine, with a speed of 7 ft. per min. (0.0355 meters per sec.) and a pressure of 270 lb. per sq. in. (19 kg. per sq. cm.).

One of the objections frequently made to friction machines in general is that, when changing to a new oil, the effect of the one that preceded can be noticed for a long time. This may lead to erroneous conclusions. The difficulty in cleaning the rubbing surfaces is emphasized in an editorial in *Engineering*[27] in which, referring to Deeley, the statement is made,

> In his view a good lubricant forms a sort of quasi-chemical composition with metallic surfaces, and is with very great difficulty dislodged therefrom. In fact, to remove the oily film thus formed it is necessary to grind away the surface under water, it being impossible to wipe it clean and very difficult, perhaps impracticable, to dissolve it off.

Table 7 seems to refute this. It is believed possible that the idea of persisting films originated from noting that the friction did not change, as was expected, when the oil was changed; but this does not take into consideration the fact that, under certain conditions as in the Bureau of Standards tests, friction depends very slightly upon the kind of lubricant and can be changed only by a change in smoothness of the rubbing surfaces due to wear.

That fatty oils are superior to mineral oils when there is incomplete film lubrication, appears to have been proved unmistakably, but the reasons given for this superiority are much less satisfactory. Alford[28] says that oiliness has been defined as

> That property of an oil that influences the change in viscosity when the oil is under pressure; or, as that property that influences the intensifying of the viscosity in the portion of the oil film within the region of attraction of the surface molecules of the metals of bearing and journal.

Since it is generally recognized that animal and vegetable oils have greater oiliness than mineral oils, it would be expected from the first part of this definition that the former oils would increase in viscosity, with an increase in pressure, faster than mineral oils increase in viscosity. That this is far from being the case was found by Deeley,[29] who observed that

> Raising the pressure to 900 atmospheres increased the viscosity of vegetable and animal oils 4 times and that of mineral oils 16 times, but viscosity was clearly not the only factor to be considered.

Dunstan and Thole,[30] express a similar opinion, saying

> We feel that some other more definite criterion is needed and we propose to combine with the viscosity the determination of the surface tension, adopting for the measurement of the latter property the weight of a falling drop. . . . . A lubricating oil should contain a certain proportion of unsaturated hydrocarbons. . . . . If this view is correct, acid treatment of a lubricating oil in the course of its production should be reduced to a minimum, since it tends to remove not only the harmful resins but also the unsaturated hydrocarbons that are valuable on account of their high viscosity and body. The physical condition of a good lubricant is probably colloidal.

The idea that acid treatment is injurious and colloids beneficial has been amplified by Acheson.[31] Wells and Southcombe[32] found that surface tension, as ordinarily measured, had little significance, but that differences in oiliness, or body, were indicated by the interfacial tension between the lubricant and the adjacent metal. The theory is somewhat uncertain because it depends upon the assumption that the size of a drop formed under water is an indication of this interfacial tension. By using the drop apparatus of Donnan,[33] Wells and Southcombe found that the interfacial tension was less for vegetable and animal oils than for mineral oils, but that the addition of a relatively minute amount of fatty acid to a neutral mineral oil reduces the tension to that of a commercial animal or vegetable oil or compounded lubricating oil.

The possibility that good oiliness is due to high adhesion or adsorption is often overlooked on account of the assumption that adhesion is always adequate. Ever since Warburg[34] showed that there was no slip at the walls of a capillary tube, all equations of hydrodynamics have been simplified by making the coefficient of adhesion equal to infinity; although Warburg merely showed an absence of slip under the conditions of his tests, and did not prove that adhesion or adsorption would be sufficient to prevent slip if the shearing forces were increased greatly. In cases of high pressure and insufficient supply of lubricant, the load will be concentrated on a small area, the film will be extremely thin and, accordingly, the shearing stresses will be very high. Thus, in an article on the lubrication of gear teeth,[35] it was shown that in turbine reduction-gears the thickness of the oil film between the teeth was of the order of 0.000125 in. (0.00032 cm.).

A committee of the American Society of Mechanical Engineers[36] attempted to cause slip at the boundaries, by the use of even thinner films with a tapered plug rotating in a ring. They were unsuccessful, however, and concluded that

> With films as thin as 0.000025 in. (0.000064 cm.) and rates of shear up to 261,000 radians per sec., at atmospheric pressure and temperature, there was no indication of slip and no deviation from the ordinary law of viscosity that could not be attributed to inaccuracy of the fitted surfaces.

Thus, while there is no definite proof in regard to the cause of variations in oiliness, the most promising theory appears to be that good oiliness is due to low interfacial tension between the lubricant and the adjacent metallic surfaces, aided perhaps by selective adsorption of unsaturated hydrocarbons, colloids or fatty acids.

SERVICE TESTS

In spite of the large amount of work that has been done with oil-friction testing-machines in the attempt to test the quality or oiliness of lubricants, there are

[27] See *Engineering*, vol. 108, p. 755.

[28] See Bearings and Their Lubrication, by L. P. Alford, p. 112.

[29] See *Engineering*, vol. 108, p. 758.

[30] See *Journal of the Institution of Petroleum Technologists*, vol. 4, pp. 200 and 206.

[31] See *The Forum*, May, September, October and December, 1919.

[32] See *Journal of the Society of Chemical Industry* (London), vol. 39, p. 51T.

[33] See *Zeitschrift für Physikalische Chemie*, vol. 31, p. 42; and Circular No. 124 of the Paint Manufacturers' Association of the United States.

[34] See *Annalen der Physik und Chemie*, vol. 140, p. 367.

[35] See *Engineering*, vol. 102, p. 119; and *Proceedings of the Physical Society of London*, vol. 32, part 2, p. 148.

[36] See *Journal of the American Society of Mechanical Engineers*, vol. 41, p. 537.

many experimenters who agree with Jacobus[37] that experience in making friction tests has led to the conviction that results obtained in a laboratory give no indication of the value of an oil as a lubricant in practical use. It is believed that this conclusion is too sweeping, although considerable caution must be used in interpreting the results of laboratory as well as of service tests. On account of dissatisfaction with the former, there is a strong tendency to discard them altogether and to rely on service tests. It is believed, however, that these may lead to as many erroneous conclusions as tests made with the worst friction-machines. In making a service test, a run is made on the oil previously used and then this oil is replaced by a new brand, recommended by the engineer conducting the tests. The new brand of oil often shows say 20 per cent lower friction. As a saving of 20 per cent is a considerable item when measured at the coal pile, the manufacturer readily agrees to buy the new brand of oil. Yet the apparent superiority of the new brand may be due merely to its lower viscosity, or to the higher temperature of a warmer day at the time of the second run.

Let it be assumed that there are ring-oilers, forced feed or other means of insuring complete film lubrication, so that the friction is proportional to the viscosity. Then, if the average bearing temperature is 100 deg. fahr. (37.8 deg. cent.) and the oil has a Saybolt universal viscosity of 300 sec. at this temperature, the change of viscosity and hence the change of friction will be at least 2.0 per cent per deg. fahr. (3.6 per cent per deg. cent.). A change of temperature of only 10.0 deg. fahr. (5.6 deg. cent.) is therefore all that would be necessary to produce what would appear to be the remarkable increased "lubricating efficiency" of the new oil. Even if care is taken that the two runs are made at the same temperature, the new oil selected may be of lower viscosity and hence show a lower friction. However, this is not the only point to be considered, since freedom from breakdowns and delays is of more vital importance to manufacturers than the minimum friction. The ratio of the viscosity of the oil under service conditions to the viscosity of minimum friction can be regarded as a measure of the factor of safety against seizure, and it is not always an advantage to reduce the friction at the cost of a decrease in the factor of safety. If the viscosity of minimum friction could be decreased, it would be possible to decrease the viscosity, and hence to decrease the friction, without any decrease in the factor of safety; but it seems improbable that means will be discovered for accomplishing this, since the viscosity of minimum friction has been shown to be a definite function of pressure, speed and clearance in the bearing. It would, however, be safe to employ a lower factor of safety if the danger of seizure could be reduced when the oil film is incomplete, and this is the purpose of adding solid lubricants in suspension.

The value of graphite in cases of incomplete film lubrication is pointed out in a Memorandum on Solid Lubricants,[38] in which it is stated

> Opinions appear to be unanimous that, when using graphite, motorcycle, automobile and stationary gas engines start more easily and with greater freedom. Speaking generally, half the friction in an internal-combustion engine is piston friction; the lubricating oil film is probably never complete and a certain amount of metallic contact, or dry friction, takes place. In the United States, colloidal graphite appears to be extensively used for the initial "running-in" of automobile engines; it is said to save considerable time in producing a good surface and gives the engine a good internal "skin" before leaving the builders' works.

A committee report of the Automobile Club of America[39] is of interest in this connection, but it should be realized that an automobile engine is a complicated machine, and that the interpretation of results is an even more difficult problem than with friction machines. Very high pressures have been carried by the Kingsbury and the Michell thrust-bearings[40] without excessive friction; but this is due to the peculiar construction of the bearings, which utilize the wedging action of the oil film, and is not an indication of the superiority of any lubricant.

Desirable Features of Oil-Friction Testing-Machines

It is safe to say that no one testing machine can solve all the problems of lubrication. Such questions as the effect of centrifugal force in causing deposits of sediment, the effect of reciprocating motion or the quantity of oil actually reaching a given rubbing surface, must be solved by service tests or by special machines that are simplified commercial machines; for example, the cylinder friction and lubrication testing apparatus of A. E. Flowers,[41] the Sternol machine[42] for engine cylinder oils and greases, and the Golden machine[43] for greases. Many problems in regard to deterioration in use can be solved best in the chemical laboratory. A friction machine especially suited to test oiliness is of greatest interest, therefore, to the lubricating engineer, leaving it to the machine designer to experiment with the laws of lubrication or to make special tests on special machines. No machine on the market comprises all of the following desirable features:

(1) Means for attaining as high a pressure as possible without danger of an inconveniently rapid change in area of rubbing surface due to wear. In the Lumet[44] machine, the load is concentrated on a small area by using four friction blocks forced by oil pressure against the inside of a hollow cylinder. In the Deprez and Napoli[45] machine, there are three blocks pressed against a disc. In Deeley's hand-driven machine, there are three pegs as previously described. It is important that the whole machine should be kept small and light so that the load can be applied or the machine calibrated without the use of excessively heavy weights, although this is not so essential if the load is hydraulically applied. Kingsbury[46] had means for releasing the pressure on the bearing without changing the pressure adjustment

(2) The drive should be so arranged that a sufficiently low speed can be reached; this is 9 in. per min. (0.0038 meters per sec.) according to Archbutt and Deeley.[47] A variable speed is obtained by a friction drive in the Schmitz[48] machine, which

[37] See *Journal of the American Society of Mechanical Engineers*, vol. 32, p. 825.

[38] See Bulletin No. 4 of the Department of Scientific and Industrial Research, London, p. 25; and *Aeronautics*, vol. 18, p. 195.

[39] See *Journal of the Automobile Club of America*, vol. 1, p. 208.

[40] See *Engineering*, vol. 107, pp. 502 and 765; *Motorship*, vol. 4, p. 28; and *Journal of the American Society of Mechanical Engineers*, vol. 41, p. 915.

[41] See *Proceedings of the American Society for Testing Materials*, vol. 15, part 2, p. 399.

[42] See *Engineering*, vol. 93, p. 871.

[43] See *Journal of the American Society of Mechanical Engineers*, vol. 35, p. 1143.

[44] See *Comptes Rendus*, vol. 158, p. 172.

[45] See *Dingler's Polytechnisches Journal*, vol. 226, p. 30; and *Revue Industrielle*, vol. 8, p. 53.

[46] See *Transactions of the American Society of Mechanical Engineers*, vol. 24, p. 147.

[47] See Lubrication and Lubricants, by L. Archbutt and R. M. Deeley, p. 384.

[48] See *Zeitschrift für Angewandte Chemie*, vol. 27, p. 468.

appears to be an innovation. It is desirable that the direction of rotation be reversible for facilitating the running-in of bearings. A revolution-counter is satisfactory for measuring the speed, although it would be convenient to use a tachometer also

(3) A sensitive and easily calibrated method of measuring friction. This probably would exclude the possibility of measuring dry and fluid friction on the same machine

(4) Means for supplying the lubricant in unlimited or in definitely measured quantities, together with a device for spreading it uniformly over the rubbing surfaces. A machine with forced-feed lubrication is in use at the engineering experiment station, at Annapolis,[49] and Alexander's[50] machine has both forced feed and other means for applying the lubricant

(5) Means for measuring the pressure in the oil film. This is of importance because it determines the proper point for the admission of the lubricant

(6) Means for measuring the temperature of the oil film. This could be accomplished by the insertion of a thermocouple in the bearing, in a pocket connected with the clearance space, but with a completely encased bearing, as in the machines of Kingsbury and of Meyers, this probably would not be necessary

(7) Means for controlling the temperature of the bearing, for both accuracy and to save time in testing. Goodman says that "it is hopeless to get reliable and consistent results in any bearing-testing machine unless the temperature is very carefully controlled"

(8) Means for observing the point of seizure accurately, and to prevent roughening of bearing and journal when seizure occurs. In the Hopps[51] machine, an automatic belt-shifting device operates on approaching seizure and stops the machine

(9) Means for measuring and adjusting the clearance or film thickness. This might be accomplished by a conical journal, as in the machine of Moore and Richter,[52] but the difficulties of obtaining a perfect fit in the bearing would be increased

(10) Means for changing the rubbing surfaces readily to permit the study of wear, bearing metals and efficiency of oil-grooves; and, more especially, for maintaining the rubbing surfaces at a constant smoothness when testing lubricants

Nine of the above stated requirements could be met with a journal-friction machine, but the attainment of the tenth requirement seems well-nigh impossible. Yet this last requirement is the most important of all, because it was evident from the Bureau of Standards tests that it is futile, or at least very wasteful of time and effort, to use a machine in which means are not provided to maintain rubbing surfaces of uniform smoothness. At first sight it might be considered possible to supply a journal with an interchangeable sleeve; then, the sleeve could be removed as often as desired and subjected to a standardized polishing process that would restore it to its original smoothness. The objection to this scheme is that any such polishing would change the radius of curvature and hence change the fit or the film thickness.

The best method of overcoming the difficulty appears to be by abandoning the journal type of machine entirely and adopting a lower disc with the friction applied by an upper disc, annulus or one or more blocks, the rubbing surfaces being on interchangeable veneers that can be removed for polishing. While disc machines have not been used as often as journal machines, those of Woodbury,[53] Kapff[54] and Hislop[55] are mentioned, the last being a composite machine to test journal, disc or cylinder friction. Archbutt and Deeley[56] discuss the suitability of disc and collar friction machines for oil testing, as follows:

> The wedging action of the lubricant, resulting from the different radii of the surfaces of cylindrical journals and the brasses that rest upon them, does not affect the lubrication of collar or disc-shaped surfaces to any very great extent. On this account, the loads that such flat bearings will carry are about one-eighth part of those that may be put upon journals. Collar and disc lubrication depends mainly for its efficiency upon the oiliness or greasiness of the lubricant used. Such bearings would, therefore, seem to be well calculated to give good results in oil-testing machines. Of course, they will always give comparatively high friction resistances and therefore they must not be regarded as suitable for comparison with those obtained with the cylindrical bearings of actual working machines, or machine tools. However, as the conditions that obtain in lubricated bearings become better understood, it seems likely that disc or collar machines, highly loaded and running at moderate speeds, will be more and more extensively used for oil testing purposes.

The possibility of maintaining a constant smoothness of rubbing surfaces adds one more reason for the use of disc oil-friction testing-machines to those enumerated in the above quotation.

Conclusions

(1) In comparing viscosity and friction it is necessary to use a unit of absolute viscosity, preferably the poise or centimeter-gram-second unit

(2) The viscosity in poises can be calculated from times of flow in seconds by suitable equations that are given for the viscosimeters most frequently used

(3) In estimating the change of viscosity with the temperature, it is convenient to make use of the observed fact that, with certain restrictions, the logarithmic viscosity-temperature graphs are straight lines which meet at a point

(4) Friction tests with complete film lubrication can give no information in regard to the quality of a lubricant, and viscosity is measured more readily with a viscosimeter

(5) The only use of a friction-testing machine for determining quality of a lubricant is in measuring oiliness, and this must be done at high pressures, low speeds or other conditions which cause incomplete film lubrication. It can be assumed that the pressure must be over 800 lb. per sq. in. (56.2 kg. per sq. cm.) or the speed less than 40 ft. per min. (0.20 meters per sec.)

(6) Bearing metals also should be tested with incomplete film lubrication

(7) It is impracticable to keep a constant smoothness of rubbing surfaces with a journal bearing, so that changes in friction, commonly supposed to be due to changes in quality of lubricant, are generally due to changes in smoothness

---

[49] See *Journal of the American Society of Naval Engineers*, vol. 26, p. 554.

[50] See *The Engineer* (London), vol. 108, p. 291.

[51] See *Engineering*, vol. 82, p. 594.

[52] See *Journal of the American Society of Mechanical Engineers*, vol. 39, p. 734.

[53] See *Transactions of the American Society of Mechanical Engineers*, vol. 1, p. 74; also, vol. 6, p. 136.

[54] See *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 42, p. 553.

[55] See *Engineering*, vol. 96, p. 254.

[56] See Lubrication and Lubricants, by L. Archbutt and R. M. Deeley, p. 408.

(8) Service tests are even more untrustworthy than friction tests, because there are a multitude of bearings whose temperature cannot be controlled or estimated readily

(9) The best solution of the difficulty appears to be the use of a disc machine. The disc could be kept of constant smoothness by removing an interchangeable veneer and subjecting it to a standardized polishing process after the test of each oil, if necessary. A journal could not be kept polished in this way because the radius of curvature, and consequently the film thickness, would be changed

MARKETING GRAIN

THE commercial life of America is more closely interwoven with the grain trade than many people suppose. Out through the Middle West wheat has always been a frontier crop; every section started as a one-crop-wheat region. Money came in only once a year, directly after harvest. Even after the coming of diversification the fall of the year is the time when farmers cash in on their season's work. This being true, it is only natural that all notes and bills due from farmers should be made payable in the fall. Likewise it is natural that jobbers, wholesalers and manufacturers should expect the heaviest payments after the annual harvest.

The entire commercial system of the country has been built around the harvest season. The railroads prepare for a heavy movement of freight, the banks prepare for a flow of currency and credits into the agricultural districts to finance crop movement, manufacturers in the East bear in mind that crop-moving time is not a good time for them to borrow money, country bankers and merchants look sharply after collections, and the Western banks expect payments on the negotiable paper they have been carrying. There is a flow of money from the East to the South and West every fall; then a counterflow in the winter. In the spring, when planting-time comes, there is another but smaller westward flow of money and credits.

Since the country is all tied together commercially and industrially and the well-being of any class depends upon the welfare of every other class, it seems clear that what the farmers should strive for, in addition to equal opportunity between buyer and seller, is equal justice between buyer, seller and ultimate consumer.

Some leaders think that the farmers should control the terminal elevators and establish a big central cash-market where they can sell from samples. They point out that the terminal elevators not only receive storage charges but are able to clean and mix and regrade and thus make another profit. With a system of bonded warehouses and some means of using warehouse receipts for securing loans, together with terminal warehouses and a cash market, some of the farm leaders think it will not be necessary nor perhaps wise to recommend anything more comprehensive in the way of control. They realize that the proposal of a very radical change would mean a complete realignment of the methods of doing all business, probably causing no end of opposition and loss of good will.

When it comes to control of production the present leaders believe that this can be best left to individual judgment, provided the individuals are given unquestioned world-crop facts upon which to base their judgment. A world-wide Governmental crop-reporting service, with daily reports sent out to all parts of the country, would be of inestimable value to the farmers at planting time and curb the effect of market rumors that so frequently affect prices on the exchanges.

The farmers already own and control nearly 5000 country elevators, and these doubtless will and should be increased. They may find it advisable to take a hand in terminal marketing both as members of the exchanges and through the creation of a big cash market. The whole country is looking forward hopefully to a sane, constructive program of marketing that all interests can indorse.—P. S. Rose in *Country Gentleman.*

ENGINEERING EDUCATION

IN previous years the first consideration of those contemplating studying engineering has been how quickly they can finish the course and get out and earn money. The purely commercial point of view has been too much evident for the good of any profession, and especially so far as the impression of the public and its attitude toward the engineer are concerned. A better professional spirit no doubt is inculcated through a greater familiarity with those subjects dealing with the political, social and economic progress of humanity. It would bring the engineer closer to the public.

To my mind the physician, lawyer and minister come more closely into contact with the great majority of the people than does the engineer, and furthermore devote more time to matters that are given daily publicity in the newspapers and other publications. It is therefore to be expected that they are given greater recognition by society. This may be due not so much to their having been trained in the "higher education" any more than engineers, for sometimes the contrary appears to be evident, judging from the position taken by some of them on important questions concerning the best interests of the public.

The aloofness of engineers in general from association with the lay public in helping to determine public policy and assisting in clarifying the minds of non-technical men in matters that may need at times the benefit of the judgment and imagination of the scientifically trained person, and even in cases where scientific or technical questions are not involved, would continue to keep the engineer in the background so long as that attitude is maintained. Commercial, governmental and public as well as semi-public officials and committees would welcome the service that engineers could bring into their various deliberations on moot questions and discussions.

The higher cultural training for the engineer would be more apt to create in him a greater interest and understanding of public affairs and greater realization that the interest of the engineer is bound up with that of the public. He will then more frequently find his place willingly and naturally alongside of men of other professions on directorates of large and small corporations, as heads of large industries and commercial or public organizations and on their committees. The public in its press would soon recognize the contribution of the engineer to the general public welfare and his lack of recognition by society would no longer be a subject calling for serious consideration by all branches of the profession.

The lack of a definite constructive policy toward developing an apprenticeship for engineers and skilled labor, is a condition that today underlies a great many of our economic troubles.

In Europe it would be evident to any American engineer visiting there, how different the attitude of the public is toward the technical professions, how much more the engineer and engineering associations are devoted to an interest in public affairs, and how much they assist in formulating policies and activities. The higher cultural education generally of European engineers is perhaps accountable for this.
—Maurice Deutsch in *Engineering News-Record.*

RAILROAD ELECTRIFICATION

RAILROAD electrification, perhaps, appeals to a larger part of the public than power for industrial use. For 20 years or more the electrification of railroads has been a subject of general interest. From time to time, as certain railroads have changed from steam to electrical operation for portions of their lines, the passing of the steam locomotive has been confidently predicted by experts who have been impressed with the superiority of electric traction, but the steam locomotive not only appears to be holding its own, but by notable improvements in design and appurtenances seems recently to have taken a new lease of life. Outside of the work on the Chicago, Milwaukee & St. Paul Railway there have been very few electrical installations in trunk lines in the past 4 or 5 years.

Advantages of Electrification

The major advantages of electrification are well known. In general they include increased line capacity, because of increased train speed and heavier train loading; fuel economy, because of the more efficient conversion of heat units into power; lower maintenance costs, because electric locomotives require less repairs than steam locomotives of equal capacity; and increased serviceable locomotive hours, because the electric locomotives can be used more continuously and require less terminal attention between trips.

Besides these strictly operating features there are important social advantages. These appeal particularly to the general public. The elimination of smoke makes traveling more comfortable and adds to the value of nearby property. Electric traction has made possible the remarkable development of the property surrounding and the track approaches to the Grand Central Terminal. Electrification of the lines radiating from Boston, as a single example, would be of immense value to the community by abating the smoke nuisance, reducing noise, adding to terminal capacity, and increasing property values. Without electricity as motive power it would be impracticable to operate trains through tunnels such as those in New York City, Baltimore and Detroit, the Hoosac Tunnel of the Boston & Maine, the Cascade Tunnel of the Great Northern and others that might be named. The electrification of the mountain grades of the St. Paul and Norfolk & Western roads has made heavier trains possible, has, by regenerative braking, reduced the risk of handling heavy trains on descending grades and has increased road capacity.

Problem One of Finance

Practically all of the electrical installations on trunk lines have been designed to meet special operating conditions, such as tunnels or city terminals. No large railroad has been completely electrified. There is an absence of data that can be used in studies of complete electrification. Railroad executives therefore will be much interested in the Superpower Survey, hoping that it may contain information that can be applied to their local conditions. The typical railroad executive recognizes the advantages of electrical operation. He knows that it will eventually displace steam, at least on lines of heavy traffic and in congested terminals. For his own line under these conditions he would welcome the advent of electricity if a fairy godmother would provide the capital funds and make it possible to earn the additional carrying charges. The problem is not one of engineering. It is essentially one of finance.

If the estimates of the Superpower Survey engineers as to savings in expenses and return on capital investment could be accepted without reservation the financial problem would be easier of solution. Unfortunately, however, this is not the case. The figures are subject to material qualification. There is evidence of an inclination to go out of bounds in making a case in favor of electricity and against steam. The zeal of the electrical engineer, who is firmly convinced as to the general soundness of his conclusions, is only natural but the report would carry much greater weight if it were less biased.

For example, in the item of fuel the electrical engineers have assumed that a steam locomotive requires 7½ lb. of fuel for each kilowatt-hour of work at the rim of the drivers. Against this they set an estimate of 2 lb. under electrical operation. From these data it is assumed that electrification will save two-thirds of the fuel bill.

It should be noted, however, that the estimate for the steam locomotive is based on experiments made 11 years ago on the St. Paul, with a type of locomotive now considered as practically obsolete. It was not as powerful as the typical locomotive of today, nor was it equipped with other devices now common on modern locomotives. A comparative test with the heavier locomotive of today, equipped with modern appliances for economizing in fuel, would give far different results. The estimate for fuel consumption under electrical operation was based on the performance of a powerplant of modern design.

Fuel Saving About One-Third

It is interesting to compare this theoretical saving of two-thirds of the fuel with the actual figures for the Norfolk & Western. In discussing the subject before a joint meeting of the societies of Electrical and Mechanical Engineers at New York City in October, 1920, the chief electrical engineer of that road stated that a comparison of fuel consumption on the electrified divisions with tests made with modernized Mallet type locomotives under similar conditions indicated that the saving in fuel by electrical operation was 29.3 per cent. This is less than one-third. If the Superpower Survey engineers had assumed a saving of one-third instead of two-thirds, the former is closer to the facts, the estimated fuel savings would be cut in two. A tendency to favor electrification is shown also in other items, such as in the allowance for steam locomotives released.

As has already been stated, the problem is essentially one of finance. In the case of a railroad that has an investment in road and equipment of, say, $100,000 per mile, something more than a questionable return of 14 per cent is needed to induce recommendations for an investment, of, say, $40,000 more per mile for electrification. On every hand there are needs for additional investments of other kinds that without question will yield more than 14 per cent.

Change Will Come Piecemeal

The Superpower Survey will probably stimulate further discussion of railroad electrification. Notwithstanding the defect that has been mentioned, the report is constructive and should be regarded as a valuable contribution to engineering and economic literature. When the railroads are again on their feet there will probably be further extensions of electrification where the conditions are most favorable.

It is improbable, however, that electrification on any such scale as is recommended by the report will be attempted. It will come piecemeal and gradually. The electrical engineers still have much to learn. The electric locomotive is still in the experimental stage. It is likely to undergo many changes in design and the experts have yet to agree on important fundamentals. While the electrical engineers are fighting among themselves the battle of alternating versus direct current and overhead construction versus third rail the mechanical engineers are unwilling to allow their electrical colleagues to stage the obsequies for the steam locomotive at the present time.—Prof. W. J. Cunningham in *New York Evening Post.*

Continuous Die Rolling

By G. R. Norton[1]

Annual Meeting Paper *Illustrated with* Photographs

The process of continuous die rolling and the products possible with this method of manufacture are described and illustrated. The improvements that have been made were the result of efforts to produce more complicated sections by this process, with greater accuracy, and these are discussed at some length.

The physical characteristics of steel that must be considered are commented upon and forming that is effected in one pass is described, consideration being given the requirements of rolled forging blanks.

The cost of operation is treated and the equipment used is discussed, showing how this process differs from other methods of making the same things, as to both the operations necessary and the character of the product.

Continuous die rolling is the process of producing bars in which the form of cross-section is varied according to impressions sunk in the pair of rolls between which the final pass is made. At each revolution of the rolls the design cut in their surfaces is repeated on the bar passing between them, and the number of these repetitions is limited only by the length of the bar as is shown in Fig. 1.

Fig. 1—Tie Rods Produced by the Continuous Die Rolling Process as They Are Delivered from the Rolls

Wagon-box straps and axle-clip sections have been produced in this manner for years. In these bars, a round alternates with a half-oval or bevel-edged flat and the change in section is accomplished by passing a round bar between the rolls, allowing the bar to pass for a certain distance without change, after which it is flattened and spread for the desired length of this part. The number of round and flat sections produced at each revolution will, of course, depend on their lengths and the diameters of the rolls.

In rolling sections of this character it is not necessary that impressions be formed in both rolls, because the round has been produced by straight rolling and it is only necessary to change its shape; so, one roll can have a plain surface with the impression cut in its mate. This usually results in a slight flattening of the round, which would be objectionable if great accuracy of size were required. The bars become oversized as the rolls wear in service and, if dressing is done by turning off the surfaces of the rolls and recutting the impressions, a loss in circumferential length results which changes the lengths of the impressions.

Improvements in the Art

Continuous die rolling as developed by the Witherow Steel Co. has as its basis the production of more complicated sections with greater accuracy. This is accomplished by building up the active surfaces of the rolls, instead of sinking impressions in the ordinary roll casting. Cast or forged rings of material suitable to the character of the section to be rolled are cut into segments in the outer surfaces of which complete impressions or parts of impressions are sunk, and the rings are assembled on mandrels to which they are locked. This segmental construction, or building up the groove, involves but little material as compared with a solid roll, and provides for easy and inexpensive dressings, repairs or changes. Wear on these rolls can be compensated for in various ways and the length of any impression held constant.

To produce sections symmetrical about their longitudinal axes, followed by other sections that may be offset, it is necessary to provide for the exact matching of the opposing rolls. This is done by mounting pinions on the rolls opposite the driven side. As only one roll is driven from the roll train and always in the same direction, these pinions are used to match the rolls exactly and are provided with adjusting devices for this purpose. Once the rolls are properly matched, there is no variation in the alignment of the impressions. It can be seen easily that, to handle this class of work economically, considerably more equipment than one finishing stand of rolls is necessary. The leader or bar on which the forming pass is made cannot in all cases be a predetermined shape, and must be found by trial. Frequently, leaders are made that do not conform to any standard commercial shapes and would, therefore, be difficult and costly to obtain. The heating, handling and rolling of single bars would operate against good production and increase costs. It is necessary, therefore, to work from billets that are roughed-down and rolled to the desired form of leader according to usual rolling practice, and finished in the same heat. This method has a considerable advantage metallurgically, because the billets are brought slowly from atmospheric to rolling temperature in continuous furnaces and can be timed to take the last pass at the proper finishing temperatures. The metal is worked uniformly and completely in one direction and its flow, as exhibited by studies of the macrostructure, is more uniform than in forging.

It should be understood clearly that continuous die rolling bears no relation to the forming of variable-section bars on forging or eccentric rolls, where the stock is cut

[1] Steel works manager, Witherow Steel Co., Pittsburgh.

FIG. 2—PHOTOMICROGRAPH MAGNIFIED 100 DIAMETERS OF AN UNTREATED ROLLED SHAFT

to the desired weight and each piece is handled individually, a large number of passes being made and the stock rotated 90 deg. at each pass.

PHYSICAL CHARACTERISTICS

Generally, it is held that hammering has a refining effect on steel and is a much superior method to rolling. Charpy showed by experiment and tests that certain physical properties are varied according to the amount of work done, independently of the method. By the amount of work done is meant the reduction of area from the original to the finished section, and the ratio of the original area to the worked area is called the coefficient of work.

To demonstrate the relative values of different processes, the amount of work done being the same, a 2-in. round billet of 0.45 per cent carbon open-hearth steel was rolled into a rear-axle drive-shaft having maximum diameters of 1-9/16 in. at the wheel and spline ends and a minimum diameter of 1-3/16 in. at the end of the long taper next to the spline end. From the same billet, duplicates of this shaft were forged and a bar was rolled 1-3/16 in. in diameter on which upsets, 1-9/16 in. in diameter were made, the lengths of the upset being the same as those of the rolled and forged shafts. The reduction of area from the billet to the smallest diameter of the shaft was 64.75 per cent, or a coefficient of work of 2.84.

Charpy impact-tests were taken on the axes of the shafts at the point of junction between the long taper and the spline end, and an examination made of the microstructure and macrostructure. A second set of shafts duplicating the first was heated to 840 deg. cent. (1544 deg. fahr.), held 15 min., quenched in oil and the impact tests and microscopic examinations repeated. Table 1 shows the result of these tests and indicates

FIG. 3—PHOTOGRAPH MAGNIFIED TO TWO DIAMETERS OF THE MACROSTRUCTURE OF A ROLLED SHAFT

FIG. 4—MICROSTRUCTURE MAGNIFIED TO 100 DIAMETERS OF AN UNTREATED FORGED SHAFT

TABLE 1—CHARPY IMPACT-TESTS

Test Made on	Energy Absorbed, ft-lb.	Strength, per cent	Increase by Treatment, per cent
Rolled Shaft, Untreated	13.59	100.0	.....
Forged Shaft, Untreated	6.32	46.5	.....
Upset Shaft, Untreated	4.85	35.7	.....
Rolled Shaft, Treated	18.06	100.0	32.9
Forged Shaft, Treated	14.08	77.8	123.0
Upset Shaft, Treated	10.83	60.0	123.2

that the method of working is a factor to be considered seriously in connection with the physical properties of steel.

Figs. 2 to 7 show a smoother and more uniform flow of metal in the rolled specimens than the others and a better refinement of grain-size before treatment. This is due to the fact that continuous die rolling is a continuous process of working rather than discontinuous as in forging, upsetting or eccentric rolling.

Forming Effected in One Pass

In continuous die rolling, it is not possible to make successive forming passes to give a product like that illustrated in Fig. 8 because of the difficulty in entering a partially formed bar at exactly the right point in the impressions in the rolls; so, the entire forming must be accomplished in one pass. When very great reductions of area are necessary, some flash or overfill will occur

Fig. 5—Photograph Magnified to Two Diameters of the Macrostructure of a Forged Shaft

as is shown in Fig. 9. The bar will be extruded between the rolls to a considerable extent but, at some point, depending upon the character of the section, the volume displacement cannot be carried further in the impressions and the rolls spring apart, relieving the grooves and allowing a portion of the metal to spread between the faces of the rolls. This flash can be controlled to some extent and may vary in thickness from 1/32 to 1/8 in. As the bar does not rotate in the pass, any flash produced is straight and can be removed easily by trimming, giving the result illustrated in Fig. 10.

It has been found that the sectional forms into which bars are changed materially affect the amount of flash and extrusion that takes place, and no rule has been found to govern all cases. However, because the rolling is in effect reducing or drawing with but little spreading action, the flash will always be considerably less than would be produced on the same piece under a hammer and, consequently, the wastage of stock is less.

Fig. 6—Photomicrograph Magnified to 100 Diameters of an Upset Shaft

Rolled Forging Blanks

Many forgings require preliminary operations, such as upsetting or drawing, before the stock is in such form as to be struck easily in finishing impressions without excessive waste and wear on dies. Frequently, so much work of this character is involved that two tools are necessary to complete the forging and, as the prelim-

Fig. 7—Photograph Magnified to Two Diameters of the Macrostructure of an Upset Shaft

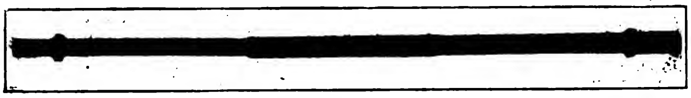


FIG. 8—A BAR WITH ROUND, SQUARE AND HEXAGONAL CROSS-SECTIONS AND BOSSES PRODUCED BY THE CONTINUOUS DIE ROLLING PROCESS

inary and finishing operations are not balanced exactly, and in many cases cannot be completed in one heat, time is lost and much expense is incurred. Continuous die rolling provides a means of supplying blanks for forging that can be struck directly in the finishing impressions in the dies, or struck after one or two edging blows if offsets or bends are required to be made. A properly designed blank can be reproduced with great accuracy, eliminating the forging scrap caused by blanks made improperly under the hammer.

Front-axle I-beam blanks, Fig. 11, that can be finished under one hammer for either the Elliott or reversed-Elliott type of axle, can be rolled. Blanks for camshafts, ready to strike for finishing, can be rolled, thus eliminating the blocking or upsetting operations and the rolling-in dies immediately preceding forging. Spring-clips can be rolled with the offsets for bending exactly as forged. A small amount of flash is produced, which requires cold-trimming before the clips are bent. Rear-axle drive-shafts can be rolled and, after trimming, are ready for hardening and machining.

The product of continuous die rolling is received from the mill in the form of long bars, in lengths that are multiples of the lengths of the individual pieces. The

FIG. 9—PHOTOGRAPH OF A REAR-AXLE SHAFT AS ROLLED SHOWING THE FLASH PRODUCED IN THE PROCESS IN THE LOWER PORTION WHILE THE SMALL INSERT IS A CROSS-SECTION OF THE SHAFT SHOWING THE RELATIVE PROPORTIONS OF THE SHAFT AND THE FLASH

length of these bars will depend upon the weight of billet used. After cooling, they are cut into ordinary mill lengths or into single pieces. After this, trimming or any finishing operations can be performed.

COST OF OPERATION

Quantity is obviously essential to the economy of operation, because the expense of cutting rolls and setting up a mill could not well be carried by a few pieces. The cost of this type of conversion naturally must be greater than ordinary conversion from billets to bars, for this work is necessary as a preliminary to the final die forming; also, to the bar-conversion cost must be added the costs of the die rolls and their maintenance, special forms of guides for delivery and adjusting gears for matching rolls. Production is decreased also, because of the necessity for lower mill speeds than are usual in rolling practice.

In addition to working out the patented features of roll construction and mill design, a long and costly series of experiments was necessary before continuous die-rolled products could be marketed and sufficient data collected to predict with reasonable accuracy the performance of any given variable section. Conversion is made on the usual basis of 1 gross ton of billets to 1 net ton of bars, the bar weight including any flash or gates between impressions of course.

EQUIPMENT USED

The size and length of pieces produced by continuous die rolling are limited only by the capacity of the mill and the diameters of rolls that can be accommodated in

FIG. 10—THE REAR-AXLE SHAFT SHOWN IN FIG. 9 AFTER TRIMMING

the housings. The equipment operated by the Witherow Steel Co. covers sections from 5/16 in. in diameter to 3-in. squares; and the lengths of individual impressions may vary from a fraction of an inch to 17½ ft., rolls 68 in. in diameter being necessary for this length. The application of the product of this process is largely a matter of the study of local conditions in any manufacturing plant, but the automotive industry generally offers a wide field for its consumption by reason of its quantity-production requirements and the large number of forgings used.

No attempt has been made to do more than describe, without much detail, the operations and equipment used to manufacture by continuous die rolling, and to show how it differs from other methods of making the same things, as to both the operations necessary and the character of the product. From its beginning, the practice of rolling has been improved only along the lines of increasing the tonnage capacity of mills, without much effort to depart from the manufacture of standard rolled shapes and bars of constant area and form of section; so, the development of continuous die rolling on a commercial basis for the production of variable-section bars is something new in an industry in which few radical changes have taken place.

FIG. 11—A FRONT AXLE OF I-BEAM SECTION SHOWING THE BOSSES AND THE FLASH

This Was a Difficult Rolling Problem on Account of the Marked Changes in the Cross-Sectional Area

Chrome-Molybdenum-Steel Applications from the Consumer's Viewpoint

By C. N. Dawe[1]

Annual Meeting Paper *Illustrated with* Charts

This paper gives a plain statement of facts regarding the application of chrome-molybdenum steels, as noted by a large manufacturer of automobiles, more than 2000 tons of molybdenum steels of various compositions having been consumed in tests and the manufacture of all the important steel parts such as transmission and differential gears, rear-axle shafts, transmission shafts, steering-knuckles, steering-knuckle pins, and the like. The data of an extensive set of physical tests are given, comparing medium-carbon, chrome-molybdenum, chrome-vanadium, chrome-nickel and chrome steels, and the results are expressed by means of a merit index, taking into consideration yield-point, ultimate-strength, elongation and reduction of area.

The case-hardening grades of steel are discussed, difficulties that were encountered in the use of the low-carbon chrome-molybdenum steel in this connection being specified. The possibilities of nickel-molybdenum steel for case-hardening purposes are considered, the results so far indicating that it is a strong rival of low chrome-nickel steel, which is considered the best steel for commercial case-hardening at present.

In venturing to cover this pertinent subject it should be stated that there are so many more data yet to be obtained that it is impossible, at this time, to make a definite statement that fully covers the situation with regard to the application of commercial chrome-molybdenum steels. Such propaganda has been spread with reference to these steels and so much has been written regarding the history, possibilities, sources of supply and physical properties obtained, that there are many consumers as well as manufacturers who are looking on in a doubtful yet open frame of mind, desiring to gain further information, particularly with reference to application. It is with this in mind that I present some actual data with reference to commercial molybdenum steel noted from the viewpoint of a large consumer and not that of a fabricator or salesman. I say from the viewpoint of a consumer because, at times, the fabricator or steel manufacturer seemingly has the weird knack of always obtaining the maximum physical properties from a material he wishes to promote, and the promoter often speaks in even higher terms. However, we as consumers attempt to strike rock-bottom and note what the material will actually do under production requirements.

Before proceeding too far with the presentation of the data and conclusions drawn, I wish to emphasize the fact that every manufacturer of automobiles and automobile parts has his own peculiar problems and that frequently the means to an end in one plant is not applicable in another; therefore, there undoubtedly will be some criticism and discussion of the publication of the information given herein, although it is presented from a strictly neutral attitude and with no idea of promoting or discouraging the use of molybdenum steels.

An attempt is made to give the results of the tests made and the observations noted in as practical a manner as possible, in order that they may be easily understandable and thereby prove of commercial value. A theoretical discussion of the causes of the manner in which molybdenum steels act will be avoided, since this phase already has been well covered by those whose opinions and discussions carry much more weight because of their many years of experience in the manufacture and application of molybdenum steels. For those who are sufficiently interested, it is recommended that the recent papers of Dr. John A. Mathews[2] and Dr. G. W. Sargent[3] be read.

Molybdenum-Steel Usage

The Studebaker Corporation of America has had made and shipped to its plants over 2000 tons of molybdenum steels of various analyses. This steel has been put through production in the form of rear-axle shafts, transmission gears and shafts, steering-knuckles, steering-knuckle pins, ring gears and drive pinions; in fact, all parts for which alloy-steel is specified. Our first efforts were to determine the advisability of the adoption of that class of chrome-molybdenum steel which would be adaptable to heat-treated forgings such as steering-knuckles, steering-arms and rolled axle-shafts, water quenching of these being desired. By a process of elimination it became clear that steel containing molybdenum approximating 0.30 to 0.40 per cent, with chromium 1.00 per cent and carbon above 0.30 per cent, should be avoided when water is desired as the quenching medium and where cracker shearing is used. An analysis showing a carbon-content below 0.30 and above 0.23 per cent, with a chromium-content of 0.70 to 0.90 per cent and molybdenum 0.30 to 0.40 per cent, gives satisfactory results with water as a quenching medium, there being no cause for concern pertaining to the development of quenching cracks.

As a rule, our first interest is turned toward the physical properties of a steel as compared to those with which we already are acquainted. Having this in mind, an extensive test was run involving the pulling of approximately 400 tension-pieces turned from heat-treated stock varying in size from 7/8-in. round to 2-in. square. The sizes used were 7/8, 1 and 1 1/2-in. rounds and 2-in. squares. The three smaller sizes were obtained by forging down from the 2-in. square hot-rolled forging bars. The 2-in. square test-pieces were taken directly from the bar, no work having been put upon them. The wide heat-treating range of a given steel is a property upon which great stress always seems to be laid but, in our tests, no attempt has been made to determine this. In this present day of accurate metallurgical control we do not need a 100 to 200-deg. quenching range. What we as consumers are mostly interested in is to determine the low-

[1] Metallurgical engineer, Studebaker Corporation of America, Detroit.

[2] See *The Iron Age*, Feb. 24, 1921, p. 505.

[3] See *Transactions of the American Society for Steel Treating*, vol. 1, p. 589.

TABLE 2—RESULTS OF TESTS OF 7/8-IN. ROUNDS

Grade of Steel	Temperature, deg. fahr. Quenching	Drawing	Yield-Point as Elastic-Limit, lb. per sq. in.	Ultimate-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Number of Tests Made	Merit Index
Chrome Molybdenum	1,550 to 1,650	1,000	146,850	158,530	21.2	55.6	9	72.8
Chrome Vanadium	1,550 to 1,650	1,000	148,900	157,770	19.4	54.6	9	65.5
Chrome	1,550 to 1,650	1,000	124,637	140,124	16.9	58.1	9	53.4
Chrome Nickel	1,475 to 1,575	1,000	119,861	135,164	18.5	59.5	9	58.2
Chrome Molybdenum	1,550 to 1,650	1,100	122,733	136,966	22.5	60.7	9	74.3
Chrome Vanadium	1,550 to 1,650	1,100	127,570	140,030	22.7	57.5	9	71.5
Chrome	1,550 to 1,650	1,100	104,911	121,108	20.5	64.0	9	64.3
Chrome Nickel	1,475 to 1,575	1,100	107,266	122,888	20.5	62.8	9	63.4
Chrome Molybdenum	1,550 to 1,650	1,200	100,980	118,900	26.5	68.4	9	92.2
Chrome Vanadium	1,550 to 1,650	1,200	119,000	131,983	23.6	60.6	9	75.2
Chrome	1,550 to 1,650	1,200	97,111	113,699	21.7	64.8	9	65.0
Chrome Nickel	1,475 to 1,575	1,200	94,804	111,800	21.7	65.0	9	64.0

est quenching-temperature that can be used commercially and still obtain the maximum physical-properties. With this in mind, quenching temperatures ranging from 1550 to 1650 deg. fahr. were used in the case of the chrome-molybdenum, chrome-vanadium and chrome steels, while 1475 to 1575 deg. fahr. were used with the chrome-nickel steel.

Methods of Testing

To obtain results as nearly accurate commercially as possible, each group of test-pieces was quenched from a production furnace in the same manner as small forgings would be handled in receiving similar treatment. The drawing operations were carried on in a laboratory electric furnace so that the effect of the drawing temperature would be defined sharply. The physical properties we obtained, true to our expectations, showed occasional variations which were to our dislike, but were fairly evenly distributed over the four types of steel. In this connection, in nearly all cases, in publishing the physical properties of a given steel there is such an exact uniformity of the superiority of one steel over another, or such an exact uniformity in the variations of the elastic-limit and ultimate-strength with respect to the elongation and reduction of area under different treatments, that it is apt to throw an element of doubt into the mind of one who can appreciate the very peculiar and pronounced variations that do exist under the most accurate handling of test-pieces. The ultimate findings of the tests given herewith, however, were derived from a very broad average of results, including good and bad which we must admit is the proper way to form conclusions on a problem of this kind. The chemical analyses of the various types of steel tested are shown in Table 1.

TABLE 1—CHEMICAL ANALYSIS OF VARIOUS TYPES OF STEELS TESTED

	Chrome Molybdenum	Chrome Vanadium	Chromium	Chrome Nickel
Carbon	0.260	0.320	0.310	0.280
Manganese	0.570	0.750	0.850	0.720
Sulphur	0.020	0.033	0.012	0.012
Phosphorus	0.025	0.025	0.020	0.020
Chromium	0.800	1.030	0.910	0.580
Molybdenum	0.360	....	....	....
Vanadium	....	0.160	....	....
Nickel	....	....	....	1.270

Quenching and Drawing Temperatures

As has been stated, three quenching temperatures were used for each type of steel for each size, except for the 2-in. square as noted. Also, three drawing temperatures were used for each quench for each size, 1000, 1100 and 1200 deg. fahr.; that is, nine pieces of 7/8-in. round stock were quenched from a given quenching temperature and three were drawn at 1000 deg., three at 1100 deg., three at 1200 deg. fahr., and so on through the series. The results obtained, as shown by averages, are given in Tables 2, 3, 4 and 5.

Generally speaking, in performing tests of the above nature where we desire to note a comparison of the physical properties of certain steels in terms of the elastic-limit, ultimate-strength, reduction of area and percentage of elongation, sometimes we are confused because of the variations we obtain, and because it is practically impossible, over a large number of test-pieces, to hold any one or two factors constant so as to note the variation in the remaining factors. If we could heat-treat the test-pieces so that the elastic-limit would be the same in all, the variation in the other three remaining factors would tell the story. After having made hundreds of tests, the question then presents itself as to how best to interpret the results obtained. Without entering into any discussion on this point, I take the liberty of using the merit index suggested by H. T. Chandler, and

TABLE 3—RESULTS OF TESTS OF 1-IN. ROUNDS

Grade of Steel	Temperature, deg. fahr. Quenching	Drawing	Yield-Point as Elastic-Limit, lb. per sq. in.	Ultimate-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Number of Tests Made	Merit Index
Chrome Molybdenum	1,550 to 1,650	1,000	153,880	162,200	19.4	55.9	9	69.7
Chrome Vanadium	1,550 to 1,650	1,000	147,750	158,770	19.8	54.8	9	67.2
Chrome	1,550 to 1,650	1,000	124,872	138,066	17.0	57.9	9	53.1
Chrome Nickel	1,475 to 1,575	1,000	120,860	136,086	18.1	59.9	9	58.0
Chrome Molybdenum	1.550 to 1,650	1,100	112,400	129,000	24.7	64.7	9	84.6
Chrome Vanadium	1,550 to 1,650	1,100	127,100	139,300	23.4	58.3	9	74.8
Chrome	1,550 to 1,650	1,100	99,706	116,526	20.6	63.8	9	61.5
Chrome Nickel	1,475 to 1,575	1,100	103,740	121,330	21.1	63.6	9	65.2
Chrome Molybdenum	1,550 to 1,650	1,200	99,330	117,400	27.1	66.7	9	88.3
Chrome Vanadium	1,550 to 1,650	1,200	101,950	116,500	26.9	64.8	9	83.4
Chrome	1,550 to 1,650	1,200	96,390	112,766	21.9	66.2	9	67.7
Chrome Nickel	1,475 to 1,575	1,200	92,590	111,013	22.1	65.5	9	65.2

TABLE 4—RESULTS OF TESTS OF 1½-IN. ROUNDS

Grade of Steel	Temperature, deg. fahr. Quenching	Drawing	Yield-Point as Elastic-Limit, lb. per sq. in.	Ultimate-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Number of Tests Made	Merit Index
Chrome Molybdenum	1,550 to 1,650	1,000	147,900	157,600	20.3	57.0	9	72.2
Chrome Vanadium	1,550 to 1,650	1,000	129,800	140,200	20.9	57.6	9	66.6
Chrome	1,550 to 1,650	1,000	101,370	122,178	18.1	60.8	9	51.6
Chrome Nickel	1,475 to 1,575	1,000	103,360	123,036	18.7	61.1	9	54.1
Chrome Molybdenum	1,550 to 1,650	1,100	118,500	131,900	24.0	64.4	9	84.3
Chrome Vanadium	1,550 to 1,650	1,100	117,800	134,900	23.5	61.0	9	76.1
Chrome	1,550 to 1,650	1,100	86,770	109,710	21.9	65.0	9	61.4
Chrome Nickel	1,475 to 1,575	1,100	87,720	110,492	22.3	65.5	9	64.0
Chrome Molybdenum	1,550 to 1,650	1,200	92,900	112,400	26.9	68.8	9	88.7
Chrome Vanadium	1,550 to 1,650	1,200	102,400	118,500	26.5	67.0	9	88.8
Chrome	1,550 to 1,650	1,200	78,250	103,453	23.7	67.2	9	65.6
Chrome Nickel	1,475 to 1,575	1,200	80,417	103,577	24.6	67.8	9	70.3

presented in a paper by John D. Cutter,[4] and of expressing the results obtained above in terms of the equation

$$I = [\tfrac{1}{2}\, e(E + S) \div (100 - R)$$

where

I = the merit index
e = the percentage of elongation in 2 in.
E = the elastic-limit in terms of 1000 lb. per sq. in.; in the tests it is taken as the yield-point
R = the percentage of reduction in area
S = the ultimate-strength in terms of 1000 lb. per sq. in.

[4] See *Transactions of the American Society for Steel Treating*, vol. 1, p. 188.

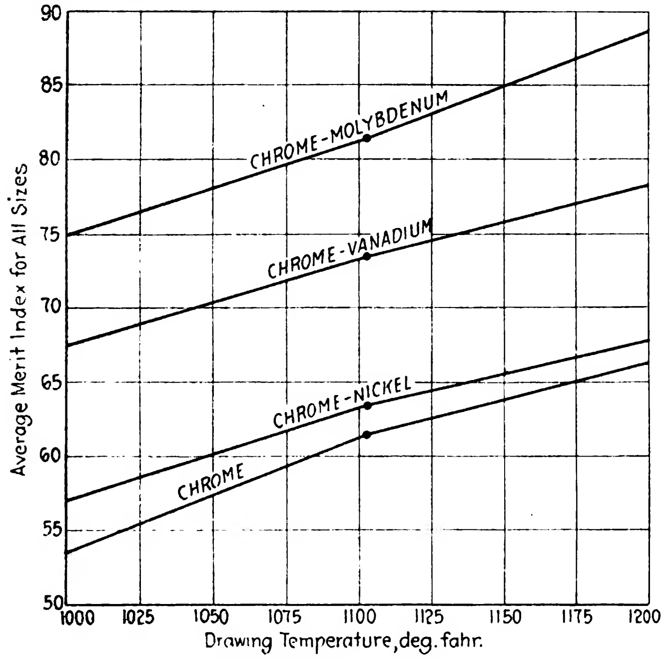


FIG. 1—CURVES SHOWING RELATION BETWEEN THE DRAWING TEMPERATURE AND THE AVERAGE MERIT INDEX FOR VARIOUS ALLOY-STEELS

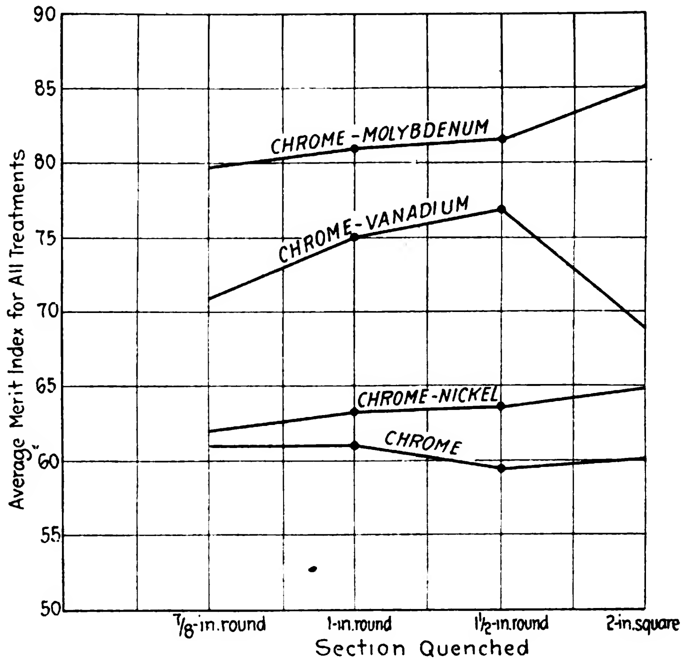


FIG. 2—CURVES SHOWING THE RELATION BETWEEN THE AVERAGE MERIT INDEX AND THE SIZE OF SECTION QUENCHED

The results are noted in Tables 2, 3, 4 and 5, while a general average is shown by the curves in Figs. 1 and 2. The above data or tests have indicated to us that chrome-molybdenum steel for heat-treated automobile parts has considerable merit. In view of the fact that this steel apparently can be produced in unlimited quantities with no danger of shortage of molybdenum, and because it has been produced and sold at a lower price than its closest competitor, chrome-vanadium steel, its adoption has been sanctioned.

With reference to its action through various stages of

TABLE 5—RESULTS OF TESTS OF 2-IN. SQUARES

Grade of Steel	Temperature, deg. fahr. Quenching	Drawing	Yield-Point as Elastic-Limit, lb. per sq. in.	Ultimate-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Number of Tests Made	Merit Index
Chrome Molybdenum	1,550 to 1,600	1,000	108,500	125,400	27.6	62.0	2	85.0
Chrome Vanadium	1,550 to 1,600	1,000	104,400	119,500	24.2	61.5	2	70.3
Chrome	1,550 to 1,600	1,000	94,375	113,050	20.7	61.3	2	55.4
Chrome Nickel	1,475 to 1,575	1,000	96,250	119,690	19.9	62.5	2	57.9
Chrome Molybdenum	1,550 to 1,600	1,100	100,500	117,200	25.4	66.5	2	82.6
Chrome Vanadium	1,550 to 1,600	1,100	112,800	127,800	24.3	59.0	2	71.3
Chrome	1,550 to 1,600	1,100	83,750	105,700	21.8	65.0	2	59.0
Chrome Nickel	1,475 to 1,575	1,100	89,375	111,350	21.8	65.0	2	62.5
Chrome Molybdenum	1,550 to 1,600	1,200	78,800	100,600	29.0	70.0	2	86.7
Chrome Vanadium	1,550 to 1,600	1,200	107,500	123,800	23.4	59.0	2	66.1
Chrome	1,550 to 1,600	1,200	77,875	99,375	24.2	68.5	2	68.1
Chrome Nickel	1,475 to 1,575	1,200	78,750	102,900	25.3	68.7	2	73.4

production, I would say that it forges entirely satisfactorily, with the particular advantage that the scale formed breaks away from the forgings very easily. With proper composition and for sizes within ordinary limits, it cold-shears as readily as the other grades of commercial alloy-steels. It responds very readily to the heat-treating operations, the percentage of forgings falling outside of the required Brinell hardnesses being very small.

With reference to its machining qualities, no figures can be given to corroborate the claims that have been made with regard to the reduction of tool costs and the like. In tests of this type, there is always doubt as to the exact uniformity of the tools performing the tests; also, the results obtained are very likely to be peculiar to a given shop and not be applicable universally. However, we have satisfied ourselves by noting the machinability of the tonnage that has passed through our shops that chrome-molybdenum steel machines at least as well as the best there is. We have not heard of a failure of any part made of this steel out of the 50,000 cars that have thus far been produced since its adoption.

Case-Hardening Grades

Approximately 90 per cent of the papers and information that have been published have referred to the forging or heat-treating grades of molybdenum steels such as are covered in the first portion of this treatise. Very few if any data have been recorded regarding the case-hardening grades, especially from the viewpoint of the consumer. Our first attention was to note whether any of the various grades of the low-carbon steels could be applied to case-hardened gears, knuckle-pins and shafts. The Studebaker Corporation is a large user of case-hardened gears and must demand the best commercial grade of steel for the purpose.

The chemical composition of the first heat experimented with showed carbon 0.130 per cent, manganese 0.400 per cent, sulphur 0.025 per cent, phosphorus 0.016 per cent, chromium 0.610 per cent and molybdenum 0.350 per cent. This analysis was abandoned for the reason that such high temperatures were required for double heat-treatment as would prove commercially impracticable. Quenching directly from the carbonizing box and using a single lower heat for hardening did not produce the desired results as regards core fracture.

The next step consisted in obtaining a higher-carbon steel to lower the quenching temperatures required and to find, if possible, a steel that would give the desired results by a single quenching temperature after carbonizing. The chemical composition of the heats obtained ran very consistently as follows: Carbon 0.190 per cent, manganese 0.540 per cent, sulphur 0.010 per cent, phosphorus 0.025 per cent, chromium 0.700 per cent and molybdenum 0.370 per cent.

The first tests made on the above analysis apparently warranted an extensive trial of this grade and, as a result, steel for 5000 cars was ordered. Upon getting into production with this material, with which all transmission parts and rear-axle gears and drive pinions were produced, certain peculiarities were noted that ordinarily could not be observed with a few trial test-pieces, the principal one perhaps being the fact that a satisfactory core fracture could not be obtained regularly; that is, after subjection to shock, the fracture would not show what is commonly called toughness but have a crystalline or granular appearance. This condition is particularly objectionable in parts that are subjected to a straightening operation and in clash gears. A further investigation proved that to obtain much better results, the part to be heat-treated had to be subjected to prolonged heating above the critical temperature of the core to bring about the proper condition before quenching and the lower heat for hardening had to be applied as quickly as possible to prevent the core from being subjected to lengthy heating at the lower temperature. This can be expressed more practically by stating that a certain gear, when heated for exactly 3 min. in a lead pot at 1425 deg. fahr. and then quenched in oil was a fairly satisfactory product; but, if held 4 min. or more in the lead pot at the same temperature, it became very brittle. This prolonged heating necessary above the critical temperature indicates, I think, a sluggishness peculiar to chrome-molybdenum steels and may account for the higher drawing-temperature permissible in the forging grades.

Effects of Carbonizing and Hardening

To indicate what happens in many cases to the core of this grade of chrome-molybdenum steel when subjected to the carbonizing and hardening treatment, Table 6 gives results of physical tests on pieces that were subjected to all of the heats of the case-hardening operations, they having been packed in sand for the carbonizing heat instead of in carbonizing compound.

TABLE 6—RESULTS OF PHYSICAL TESTS OF STEELS AFTER CASE-HARDENING[5]

How Cooled	Temperature of Quenching, deg. fahr.	Yield-Point as Elastic-Limit, lb. per sq. in.	Ultimate-Strength, lb. per sq. in	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.
Quenched from Box into Oil	1,380 deg. Oil	57,625	102,625	9.30	22.00	212
		56,250	101,250	17.20	33.75	317
		57,750	90,250	25.00	53.25	189
		55,150	92,650	21.90	46.25	228
		70,250	105,250	14.10	30.50	206
	1,400 deg. Oil	63,875	108,875	6.25	4.00	228
		77,625	107,625	.....	.....	228
		64,000	109,000	14.10	22.50	241
		75,800	113,300	7.80	3.80	225
		67,050	109,550	14.10	27.50	228
Cooled in Box, 1,650-deg. Oil	1,425 deg. Oil	80,000	115,000	12.50	32.50	229
		85,000	120,000	12.00	31.00	235
		110,500	125,250	12.40	.....	252
		97,500	118,000	15.50	28.00	248
	1,425 deg. Water	120,000	136,000	7.00	Broke Outside Gage Marks	285
		100,000	110,750	4.00		269
		107,500	119,000	4.00	.....	248
		90,000	129,000	14.50	26.00	255

[5] All test-pieces 7/8-in. round were subjected to a 14-hr. heat at a carburizing temperature of 1650 deg. fahr.

It will be noted that a very peculiar combination of properties is obtained and we naturally are inclined to attribute the results we have obtained with case-hardened parts to these conditions. These properties do not exist with carbon-molybdenum, nickel-molybdenum or chrome-nickel steel of the same carbon-content. As to chrome-vanadium steel, I cannot comment upon it because all of this type that has been experimented with contains approximately 0.11 per cent carbon.

To obtain the best possible results with the case-hardened parts it was necessary, therefore, to quench from the carbonizing box into oil and follow this by the regular double heat-treatment and a final draw at 375 to 400 deg. fahr., timing each operation as carefully as possible. There are two particular advantages that should be noted, however, in that chrome-molybdenum steel will

(*Concluded on page* 62)

THE TRUTH ABOUT COMMERCIAL AVIATION

THE Section and Extension meetings that the Society has been furthering on Commercial Aviation have met with decided success. It was stated in announcing these meetings that an effort would be made to obtain speakers who would give the truth about commercial aviation. The remarkable attendance at all of the meetings thus far held is clear proof of the public interest in the subject and indicates the eagerness with which a program of real information is greeted. The public has apparently been waiting for some time for a progress report.

The Chicago Rotary Club requested the Society to include it in the program, and Glenn L. Martin, member of the Council, at the instance of President Beecroft, addressed the Club on Nov. 22. The audience was composed of a large number of Rotarians and guests. Mr. Martin stated that, although the operation of aircraft is undoubtedly costly as compared with slower forms of transportation, this will not appreciably retard the growth of aerial transportation since the airplane has the same relation to the railroad that a taxicab has to a street-car.

A committee comprising G. P. Dorris, chairman, G. F. Kublin, F. W. Gardner, J. A. Mummert and A. H. Timmerman, arranged a most enthusiastic dinner-meeting at St. Louis on Dec. 1. The speakers included Colin M. Selph, postmaster of St. Louis; A. B. Lambert of the Missouri Aero Club, F. W. A. Vesper and Past-President J. G. Vincent. On account of its geographical location, St. Louis is destined to be one of the great aviation cross-roads. That this is very thoroughly appreciated by St. Louisans was indicated by the presence of over 200 at the dinner.

Past-President Vincent's address on the Trend of Commercial Aviation, which is printed elsewhere in this issue, was a clear analysis of the economic possibilities of the airplane for commercial work. He indicated the factors now impeding the growth of aerial transportation as a business and suggested ways of overcoming these obstacles. Postmaster Selph spoke of the success of the air mail and urged the extension of this branch of the postal service.

Perhaps the most successful meeting of the series from the standpoint of attendance was that at Detroit on Dec. 5, when a dinner was given by the Detroit Section in conjunction with the Detroit Aviation Society and the Detroit Board of Commerce in honor of Admiral William F. Fullam, U. S. N., retired. Three hundred men attended the dinner and over 600 were present at the meeting that followed. Howard E. Coffin was chairman of the special committee on arrangements. C. F. Kettering was toastmaster. There are few toastmasters in what is now the dry-toast masticating business who are the equal of "Ket."

Speakers at the Indiana Section meeting on Dec. 12 included Past-President J. G. Vincent, V. E. Clark, chief engineer of the Dayton-Wright Co., Major Kirby and Lieut. McK. Robinson of the Air Service, T. A. Flaherty, secretary of the Hoosier Aero Club, and Charles Crawford. Nearly 100 attended the dinner. J. G. Vincent, in company with V. E. Clark and B. L. Whalen, flew to Indianapolis from Dayton, the trip taking 1¼ hr. In speaking of the best methods to be employed in developing commercial aviation, Past-President Vincent stated that the extension of the air mail service now being so successfully operated is of extreme importance.

The Metropolitan Section received so many applications for dinner on the occasion of its Aviation Meeting on Dec. 15 that it was necessary to turn away a number of members. Over 130 attended the dinner and nearly double that number were present to hear the speeches which followed.

Past-President C. M. Manly, who has been prominently connected with aviation for many years, presented an abstract of J. G. Vincent's paper on the Trend of Aviation and urged the desirability of using commercial aircraft at this stage of the development in such places and under such conditions as involve least competition with other methods of transportation. He pointed out the number of opportunities for the use of aircraft where other transportation media were not at hand and showed the comparative futility of attempting to compete at this time with short-haul railroad and other well developed means of transportation.

Ralph Upson, airship designer, who has recently returned from participation in the international balloon races abroad, spoke of commercial aeronautics in Europe. One of his remarks was to the effect that while in this Country people are looking upon Europe as the leader in commercial aviation, he had found that in England and in France the same attitude is taken toward American progress and that on the whole we do not suffer by comparison.

C. F. Redden, general manager of the Aeromarine Plane & Motor Co., spoke convincingly of the fact that commercial aviation has actually arrived and said that the problem is now largely one of inducing people to take advantage of the opportunities that are available for commercial flight. He mentioned that the cost per plane-hr. is slightly over $70, of which only about $15 is for gasoline and oil. A saving, therefore, of 25 per cent in engine efficiency, with a consequent reduction in cost of fuel of perhaps $4, would lower the total cost of transportation only slightly. On the other hand, since it costs approximately as much to fly a large machine with one passenger as with 10 an increase of the number of passengers actually carried on each trip would do a great deal in lessening the cost per individual. Mr. Redden spoke of the fact that travel by aircraft is more expensive than by any other means of transportation but felt that the higher rate would be paid by those to whom a saving of time is a matter of moment.

Com. H. C. Richardson, U. S. N., discussed the relation of civil aviation to National defense and called attention to the fact that while it is difficult to convert planes from war to commercial purposes or the reverse, it is comparatively easy to construct war machines in factories primarily equipped for the building of commercial aircraft.

S. H. Philbin outlined briefly the provisions of the Wadsworth bill, now before the United States Senate, for the control of civil aviation, and spoke of the need of fundamental legislation that is essential to the welfare of the aeronautic industry.

One of the largest meetings held by the New England Section since the time of its formation last year was convened at the Engineers Club in Boston on Dec. 16. Prof. E. P. Warner gave an address on the status of commercial aviation. Among the other speakers were President Roger Amory, of the Aero Club of Massachusetts, Major E. B. Lyon, aviation officer of the First Corps Area, both of whom stressed the need for a properly equipped landing-field near the center of Boston, and C. D. LeFevre, sections secretary of the Society, who gave an outline of Past-President Vincent's paper and told what had been accomplished in the interest of commercial aviation at other Section meetings.

An interesting feature of all of these meetings was the showing of moving pictures depicting the sinking of ex-German and obsolete American battleships by aircraft bombing. These pictures, which have not been publicly shown, are spectacular in the extreme and make obvious the vulnerability of even the most heavily armored ships to this method of attack.

President Beecroft at a luncheon given in his honor by the Aero Club of Sioux City, Iowa, on Dec. 8, gave an outline of some of the recent notable achievements in commercial aviation and spoke of the work that the Society is doing through meetings in the various parts of the Country in the interest of aviation. Mr. Beecroft gave an analysis of the Wadsworth bill for the control of commercial aviation which is now before the United States Senate, and emphasized the desirability of supporting this measure. He also presented a digest of J. G. Vincent's paper on the Trend of Aviation Development. An interesting part of his talk had to do with a description of the ground organization now being used in connection with commercial aviation in France.

If it had been possible to admit the general public to the

meeting of the Pennsylvania Section of the Engineers Club of Philadelphia on Dec. 22, a large part of the Christmas congestion of passenger and express traffic of the railroads would have disappeared. At least it is safe to say that the only reason for not using airplanes for fast service, would have been due to the lack of regularly scheduled airlines in operation and not to any doubt on the part of passengers or shippers as to the advantages of aerial transportation.

It seems almost incredible that the splendid results attained by the air mail should have received such scant publicity heretofore. Second Assistant Postmaster General Shaughnessy, who told Section members and members of the Aero Club of Pennsylvania about the air mail, quoted figures which indicate that astonishing progress has been made within the last few months.

In the 3½ years since the establishment of the aerial mail service 3,400,000 plane-miles have been flown, with 30 fatalities in the entire time. During the months of July, August and September of this year, however, the air mail has flown 391,000 plane-miles exclusive of test flights and has carried 10,014,000 letters. 97.5 per cent of the scheduled trips were flown on time. There were no injuries on regular trips during the entire period.

Ralph Upson spoke of European conditions and outlined the basis of the French and the English subsidies. He believes that subsidies based either on miles flown or on a percentage of the gross receipts tend to perpetuate whatever faults may now be present. He suggested that much greater good could be accomplished by granting prize money for improvements in design, economy of operation and night flying.

William B. Stout spoke of the requirements of commercial aircraft and emphasized the necessity for lowering maintenance costs through the use of all-metal planes in place of those having wood and cloth in their construction.

THE BUSINESS CYCLE

PRODUCTION and distribution are the biggest things in business, and production is first. Production can be divided into two classes, agricultural and industrial. Everything that is not agricultural production falls under the classification of industrial. Distribution, or marketing, depends largely on production. It is folly to study statistics of marketing because marketing shows the effect, not the causes. All through the matter of prognostication of the future, differentiate between the cause and effect. If we want to look ahead we have to figure the causes, and the effects will take care of themselves. We have four conditions; commodity prices, foreign trade, the railroad companies, transportation companies, carloadings and idle cars and then retail sales, four divisions of marketing.

The third classification is labor. We study labor under three or four heads; first, wages; second, controversy; third, immigration. The fourth division we call business profits, meaning by that the earning records of corporations. Then there are business failures; of course, they are just the opposite of business profits.

Next, we have new security issues, because the volume of new securities being offered reflects more or less how conditions are as far as business profits are concerned.

Fifth, we have exchange transactions; in other words, those transactions that take place on the commodity exchanges, on the stock exchanges and on the foreign exchanges.

The sixth division we call finance. Under finance we have bank clearings, bank statements, interest rates, gold movements between countries and operations of the United States Treasury Department.

Agricultural Production

The greatest thing in business today, the cause that has more effect than any other single cause upon fluctuation in business, is agricultural production. The thing that governs agricultural production will be the climatic conditions of the country, and who could pretend to foretell climatic conditions?

As far as the business cycle is concerned, you cannot tell from current agricultural production if we are in depression or prosperity. In other words, you find that the business cycle goes on regardless of agricultural production because the farmer is looking ahead and planning for his next crop, and at that time conditions may be entirely different. Industrial production, however, is at its lowest ebb in times of depression. We know it must be so because there is one thing that is making depression.

Do prices make business? Not always. Within the last year we had cotton at 42 cents, and we have seen cotton at 11 cents. Was it easier to sell cotton at 42 cents or 11 cents? At 42 cents. In other words, it is not the prices that determine whether you get the business or not. It is the trend of prices.

In the periods of depression, ordinarily speaking, exports tend to increase and imports tend to decline. Why? Simply because when prices are low here there is a foreign demand. Why are exports not increasing now? It is on account of the monetary situation in Europe.

Wages

Wages tend upward before labor conditions start to improve which is a peculiar feature. There is a tendency to put wages down to bed-rock, because expenses have been increasing during the preceding periods, and business has been falling off during the preceding period of liquidation. Wages get abnormally low. They get to the point where the worker cannot survive, and the employers have to increase the rates despite the fact that business does not justify it, and when they are doing that they are helping themselves, but they do not realize it. They say it is an added expenditure, and the profit is small. But with that increase to labor it does not need much to get business swinging back toward normal again, and the little increase that labor gets is one of the things that helps to bring it back.

Demand and Supply

The cause of the business cycle can be expressed very simply. It is simply the maladjustment between supply and demand. In the period of prosperity production is overdone. In the period of depression production is underdone, and sooner or later the demand will get ahead of the supply. If for no other reason than that production is underdone, it is psychological that when profits are large production is increased; when profits are small, or minus, production is curtailed. At some point it develops that there is a shortage. There is a demand for the given commodity, and the supply is not sufficient. The increase in business helps one industry here and another industry there. As the result of that the improvement spreads all through the business world.—D. M. Jordan in *American Machinist*.

Pertinent Facts Concerning Malleable-Iron Castings

By ENRIQUE TOUCEDA[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

ADDRESSING the structural engineer and the purchasing agent particularly, the author discusses the relationship between them and the foundryman with regard to malleable-iron castings and enumerates foundry difficulties. The characteristics necessitating adequate gating for such castings are described and illustrated, inclusive of considerations regarding pattern design, followed by a statement of the considerations that should influence the purchasing agent when dealing with foundrymen.

Possible casting defects are described, illustrated and discussed, comment being made upon casting shrinkage and machinability. Improvements in annealing-oven construction and operation are reviewed and the records of 100 consecutive heats in different plants are tabulated. The materials for casting that compete with malleable iron are mentioned and its physical characteristics are considered in some detail.

Emphasis is placed upon the necessity for the elimination of casting shrinkage and a brief summary is made of the most important features of the paper.

IN responding to the invitation to contribute an article covering the malleable-iron casting, I find no difficulty in determining the particular details which should prove of greatest interest at present to the user and manufacturer of these castings, because the two conditions that will be referred to overshadow in importance any others concerning which it would be possible to write.

It can be predicted safely at the start that the builder of automobiles, trucks or tractors is exceedingly anxious to use any product by which it is practicable to secure an increased output at less cost than possible through the use of some other material, provided the former were found to be equally dependable. On the other hand, the founder would be pleased indeed to market all the castings he could produce if this could be done at a reasonable profit. In short, it is but logical to assume that, under the conditions stated, there should exist between the two a mutual interest that should be continually strengthened, until modified if not nullified by the appearance of some other product equally reliable and less costly, or until such a time as the purchaser, in his desire to lessen the cost of his machine, shall be unable or no longer willing to pay a fair price for the castings.

It is in connection with this relationship that I would address those interested but, in doing so, I direct my remarks particularly to the structural engineer and purchasing agent; for, irrespective of how talented or how wide their experience with these castings may have been, there are certain facts that are difficult of ascertainment, either for or against them, short of an intimate experience in their manufacture, and it is but fair to assume that very few who have occupied either of these positions have had this experience. Unfortunately, the same can be said of the foundryman whose knowledge of automobile manufacture and construction is limited to the reading of his automobile catalogue and a perusal of the illustrations. While it happens that I am affiliated with a large number of the manufacturers of these castings, I am writing, as I have done invariably in the past, with perfect candor and with the concealment of no facts in connection with these castings that it would be to the interest of automotive engineers to know. This is true to such an extent that, as we proceed, I will present some details in connection with their manufacture and inspection that I trust will prove of value to the Society. In exchange, those who are striving hard to perfect their castings would like to count upon the business sympathy of the Society and the cooperative advice of automotive engineers in a serious work that, as stated, can correctly be considered in no other light than one of mutual interest, for it is my belief that, in the case of finished parts that are required to stand great abuse, there exists no other ferrous product of equal dependability that can be machined at anywhere near equal cost.

FOUNDRY DIFFICULTIES

It will facilitate my work if we consider for the moment a few of the various difficulties that confront the foundryman in various lines of endeavor. He may be working with a metal that it is impracticable to cast free from blowholes, even through the liberal addition of alloys that are introduced solely for the purpose of combining with the occluded gases. He may be using a metal that, even when surcharged with a high degree of superheat, is so sluggish when molten that mis-runs will be in order. The metal used may be one so sensitively weak at certain temperatures, after or during solidification, that contraction on the cores or between the gates may result in a prohibitive loss due to contraction cracks. The foundryman may be working with an alloy that must be made in accordance with strict specifications as to analysis, one of the component metals of which may be very volatile, with a resultant loss and the production of a casting of incorrect composition. The melting point of another metal may be so high that, when raised to a casting temperature sufficient to run the work successfully, even a very refractory molding-sand will burn on the surface and make machining costly. Difficulties are experienced with metals that segregate, lose their fluidity quickly, are drossy, crystallize out if poured in a sand mold, and the like.

In addition to the handicaps mentioned, whether the metal used is easy or difficult to cast, all founders are confronted with what is known as the molding problem in every instance. That this problem is replete with difficulties is certain, even when reduced to its simplest terms through the use of a metal almost ideally adapted to the making of castings with minimum risk of mis-runs, and that will cast true to pattern and with good

[1] M.S.A.E.—Metallurgical and chemical engineer, Albany, N. Y.

casting surface. In the case of air-furnace hard iron, the molten iron from which malleable-iron castings are made, molding difficulties are not occasioned because of the eccentricities of the metal, but the successful production of good castings is made both difficult and complex, due for the most part to the eccentricities of the pattern design. It must be manifest, if we are dealing with a metal the fusion point of which is lower than that of any metal suitable for the production of a ferrous casting, that owing to this low melting-temperature a minimum of occluded gases will be absorbed. If, in addition, the metal has carbon, silicon and phosphorus contents so high as to yield a fluidity sufficient almost to pour needles, it is evident that something must be radically wrong if the castings are not only free from blowholes but from shrinkage as well. So far as the former trouble is concerned, when blowholes are present in a malleable-iron casting, which I believe the user will acknowledge is infrequently the case, it almost invariably is the fault of molding practice. It is due to sand that is too damp or too tightly rammed, to cores that are too compact or badly vented, or to similar causes, and rarely if ever due to occluded gases. On the other hand, when shrinkage occurs, and this is one of the most harmful and disastrous imperfections that can be present in a malleable-iron casting for reasons that will be entered into later, while the fault at times may be due to bad molding-practice, it can be stated safely that in by far too many cases the structural engineer has furnished a design that cannot be produced entirely free from this defect, even through the exercise of the highest degree of molding skill and the use of much extra metal in the form of risers and heads, the subsequent remelting of which is costly.

Adequate Gating

For molten metal to fill a void, it must not only have free entrance to it, but the entrance must be proportioned so as to admit of the void being filled completely before the entrance or, as it is commonly called, the gate, becomes closed by the gradual solidification of the metal passing through it. Let us assume that these conditions have been almost but not wholly fulfilled in the case of a void of very simple character, for example, that made by a small rectangular block, and that the metal in the gate has frozen prematurely so far as the conditions stated are concerned. In this event, while the surface of the casting will be a true replica of the void design, as must happen by reason of the fact that the molten metal as it enters the void and strikes the cold surface of the sand will freeze instantly into a very thin solid shell of similar form, there will not be a sufficient amount of molten metal present to produce a perfectly sound casting, because molten iron occupies more space than solid iron. Under these circumstances it will be found that a shrinkage or cavity will exist in the casting of a size dependent upon how much too soon the metal in the gate or void-entrance solidified, thus preventing the casting from being furnished with sufficient molten metal as solidification was progressively taking place. A hole may result in exaggerated cases, or an area of greater or less dimensions and of greater or less porosity may be produced if conditions are less bad.

Let us assume that the conditions first referred to were fulfilled as described, and that the metal in the gate and in the void freeze simultaneously. Even under these conditions a very imperfect casting will be produced, because if metal occupies less space when solid than when molten, sufficient metal still will be lacking and, in consequence, a porosity will exist that will be proportional to the metal deficiency. It is clear, therefore, that to produce a sound casting of this character it is not only essential that the metal in the gate or void entrance remain fluid for a sufficient length of time to enable the void to be filled, but provision must be made for the metal in the gate to remain fluid until after that in the void has solidified completely, in order that, as solidification in the void progresses, no cavity can remain by reason of lack of fluid metal to occupy its space continually to the vanishing point. The basic principles of pattern design and subsequent molding call for a pattern proportioned so that it is possible through the exercise of skilled molding-practice to gate and head the pattern so that the molten metal will feed to all its parts as they progressively solidify from the surface inward as the volume change takes place. When the molder's skill is exhausted and shrinkages still appear, it is not unreasonable to conclude that the pattern design should be changed.

Pattern Design

To illustrate a very important and fundamental fact to those who have to do with the design of patterns, the following simple illustration will suffice. Let us consider the case of a casting consisting of two rectangular parts of equal dimensions connected together by a rectangular member of considerably smaller cross-section, the overall size of the pattern being such that four can be placed in one flask. If gated at one end, the metal will flow in the rectangle to which the gate is attached, thence through the thin section and from it to the other rectangle. Under these conditions the entire casting must be fed from the gate as gradual solidification progresses, because molten metal can, in this case, be derived from no other source. It is certain that, when thus cast, the rectangular part farthest from the gate will be more or less unsound, for it is hardly to be expected that the small gate at one end can feed the rectangle farthest from it continuously, owing chiefly to the more rapid solidification of the metal in the much smaller section joining the two heavier parts.

Actually, this thinner section will be drawing metal from the two larger connected parts, for the metal in these will act as reservoirs to feed it and, in doing so, make certain their own unsoundness, particularly in the case of the part farthest from the gate. In order that the latter be made solid, it is essential either that the metal in the thin section be kept fluid a sufficiently long time to provide that part with a continuous supply of molten metal until its solidification is complete, or a head or reservoir must be placed upon it from which it can obtain an auxiliary supply independently of the thin part to which it is attached. However, in castings of intricate design which, in automotive castings, is the rule and not the exception, it is frequently impossible for mechanical reasons to furnish independent heads or reservoirs to each disproportionate part, and it is essential therefore that balanced solidification through a possible feeding of every part be facilitated by a proper pattern design, coupled with skilled molding-practice. To make success possible, the founder gates and heads his castings in such a manner that the feeding of the heavy parts will be accelerated to such an extent as is possible, but how often is the design such that, in spite of every expedient known to the skilled molder and of the use of a metal of the very best casting characteristics, an absolutely sound casting cannot be made For the sake of his reputation and for the good of the industry, the founder

should have the courage to refuse to use patterns from which a product free from shrinkage cannot be made.

Foundry Policy and the Purchasing Agent

In the case of a certain casting, let us assume that, through the exercise of great molding skill, the most favorable gate emplacement and correctly placed risers that jointly will weigh considerably more than the casting, it is found that solidity can be secured through use of these costly expedients. Let us assume further that the purchaser has decided to obtain these particular castings from three sources of supply. Founder No. 1 is conscientious and, through the use of very high and bulky heads and risers, is furnishing a perfectly reliable casting. Founder No. 2 is less careful and some minor shrinkage is present in his castings. Founder No. 3 is still less careful and his castings fail in service. Does the purchasing agent or the engineer analyze the situation and condemn the particular source from which these castings came, cancel the order and transfer it to Founder No. 1; or, does he suggest that the malleable casting is not to be depended upon and recommend that

Fig. 1—Sections of a Gear-Case Showing Solid Metal in the Left Portion and a Minute Amount of Shrinkage at the Right

another metal be substituted for it? If the product were apples, it is certain that at least one source of supply would be dropped because the purchaser knows a good apple on sight and that good ones are purchasable. If apples are the fruit he wants, he would be considered somewhat eccentric if, on account of having received bad apples from one source of supply, he cancelled the order with the other two sources and decided to substitute pears for apples.

The foregoing may seem far afield as a parallel case, but it appears to me to be entirely analogous. The automotive engineer has need of good malleable-iron castings because of their wonderful machinability and ability to stand great abuse in service and, should some castings fail in service, it is hardly fair to conclude that the trouble is fundamentally with the metal per se, when as a matter of fact it lies with the source of supply. The conditions referred to are exaggerated, owing to the attitude of the purchasing agent. In his perfectly legitimate desire to do the best possible for his company, he often mistakenly places price ahead of quality. We have good automobiles and we have poor ones, which fact should not condemn the automobile. In just the same manner as an automobile salesman would laugh at the man who wanted a high-grade car for the price of a fliver, the competent and conscientious malleable-iron founder should be excused if he smiles when asked to meet the price of a competitor who, instead of using the costly expedients that have been shown to be necessary to secure soundness, will ship castings that in general

Fig. 2—View Looking Down on a Gear-Case Casting with the Gates and the Risers Attached

appearance are all right but which close inspection will disclose are unsound. In the case of two sources of supply, all costs being alike in both cases except that for molding and extra metal used in risers and heads, there easily can be a difference of 2 cents per lb. in the cost of production between a casting that is perfectly sound and one that is nearly so. I recommend that, in the purchase of malleable-iron castings, the source of supply be given the weight that its importance deserves, particularly until the designing engineer awakens to the necessity of a fuller cooperation with the founder.

Let us assume that the engineer has decided to substitute another product in lieu of the malleable-iron castings. No risk will be taken in making the statement that, before the contract is signed by the vendor, he will request that he be granted permission to alter the pattern that was furnished and used by the malleable iron founder. The request will be made that he be allowed to thicken the sections here and there, that certain corners be replaced by generous fillets and other modifications such as in his opinion will better adapt the pattern to the peculiarities of his particular metal. I have no quarrel with the reasonableness of this request, because it is absolutely along the lines of commonsense, but in the majority of cases permission will be granted in such cases that strenuously was denied the malleable-iron founder, and, while I can offer no explanation for this curiously illogical situation, I can vouch for the accuracy of the statement.

Fig. 3—Side View of the Gear-Case Casting Shown in Fig. 2 Before the Gates and the Risers Were Removed

Fig. 4—A Gear-Case That Was Deformed by Sledging to Demonstrate the Ductility of the Metal

Possible Casting Defects

To illustrate in a practical manner some of the statements that have been made, we will consider Fig. 1, in which various sections cut from a gear-case shown in Figs. 2 and 3, two views of this casting with gates, runners and risers attached, can be seen. In Fig. 2 the large size of the gate at *A* should be noticed; it is so large that it is with difficulty that it can be broken off without disfiguring the casting. I also would call attention to how efficiently the heads have served to feed the casting during solidification, for the cavities at *B* in these heads practically are a direct measure of the amount of metal they supplied to the casting during its solidification period. The use of such large gates is possible owing to the introduction of a strainer core set at the bottom of the pouring sprue that serves to take care of the dirt and thus make possible gate enlargement. These heads, runners and sprues jointly weigh considerably more than the casting. In Fig. 3, the massive heads with large wells below gate level, made in this manner in order that the metal in the gate will not prematurely freeze but remain open until the solidification of the casting is completed, should be noticed.

Fig. 5—Photomicrograph Magnified 150 Diameters Showing the Structural Condition Existing in a Shrinkage

Let us now take up the lesson that can be drawn from a consideration of the sections shown in Fig. 1. It can be seen in the full half-section that one side of the casting is absolutely solid while there are two shrinks in the other side that are so small and so located that their presence would not affect the strength of the casting in such a manner as to cause it to weaken or fail in service. The section is shown, however, to illustrate how delicately balanced are the conditions that make for shrinkage or its absence. Here is a case where a casting is gated in very generous fashion, with heads that weigh more than the casting itself and are symmetrically placed; and still one side of the casting is perfectly sound while a small shrinkage is present in the other. The reason is simple. In spite of the precautions that have been taken in the use of large gates and high and bulky feeding heads symmetrically placed, a little slower feeding occurred on one side than on the other. The pattern is intricate and a slight difference in friction or in the division of the molten metal on reaching the bottom of the pouring sprue could cause the slightest difference in the rate of feeding of the two sides in a case where such extreme measures had to be taken to insure soundness. But, should a pattern be designed so that it is essential to have to go to these extremes to make soundness certain, if it is easily possible to design it in the first place so that casting difficulties are absent or, having designed it incorrectly, is it not best at least to make the slight changes that would improve the casting condition?

Fig. 6—Photomicrograph of a Normal Portion of a Casting Adjacent to the Shrinkage Illustrated in Fig. 5, Magnified 100 Diameters

I venture to state that if, without changing the total weight of the casting in question, the founder were per-

mitted to alter the thickness of certain sections at two places by an extremely small margin and deduct this weight from the heavier parts where it can be proved easily that a small amount of useless metal exists, not only would there be no unsoundness at any locality, under the present system of molding, but this result invariably could be accomplished with certainty and with considerably less waste metal. In considering the foregoing, the engineer should keep in mind at all times that air-furnace hard iron, next to gray iron, is the easiest of all ferrous metals to cast. What these particular castings are capable of enduring can be seen by reference to Fig. 4, which shows one that has been sledged down and deformed to a considerable extent.

Fig. 7—Photograph with Very Low Magnification of a Casting That Is Hard Throughout but Has the Hardest Metal at the Surface

Let us take up another phase of the shrinkage problem and make plain a most important matter; one that perhaps is not fully appreciated by the engineer or the inspector. In the case of the shrinkages in the castings we have just considered we have concluded that, as located and in view of their small size, they would not cause the castings to fail in service. Let us assume that the same statement would hold true if a minute shrinkage were located at some point where machining would be required. In this case, however, much damage could be caused, for shrinkage is really synonymous with hardness. Contrary to the opinion of some, the hard spot due to segregation is not an evil inherent in the malleable-iron casting. A moment's thought should convince the engineer of this fact, for the sections are so thin that solidification takes place too quickly to admit of this trouble. When a hard spot occurs in a malleable-iron casting, it invariably will be found that it is due to the presence of a shrinkage, a matter that I demonstrated very early in my investigations. Therefore, it can be accepted as a fact that heavy losses can be sustained by the manufacturer if even slight shrinkages occur near surfaces that have to be machined.

Machinability

In the micrograph reproduced in Fig. 5 the structural condition existing in a shrinkage can be seen. This should be compared with that of the sound and normal metal adjacent to it that is shown in Fig. 6. For reasons not fully understood, free cementite, the hardest constituent that can occur in iron or steel, usually is associated with a shrinkage area and it is to this constituent that the hardness is due. That shrinkage is a defect that should not be tolerated in a casting is true. The purchaser should, through rigid inspection, safeguard

Fig. 8—A Very Low-Magnification Photograph of a Casting That Was Hard to Machine on Account of a Hard Inner Border of Pearlite between the Surface Layer and the Softer Metal Underneath

himself in this particular, but he should approach this trouble with tolerance and contribute his share toward eliminating it. It is unreasonable that the founder be required to bear the entire burden if the dominant part actually rests on the shoulders of another. On the other hand, when castings are received that are hard to machine for reasons other than shrinkage, the fault can be wholly attributed to the founder. Such conditions can be occasioned even in the case of castings of ideal composition due to various causes, through failure to anneal them at a high enough temperature for a sufficient length of time, by too low an annealing temperature or by a too rapid rate of cooling, in all of which cases the castings will be uniformly hard throughout. Such a case is shown in Fig. 7.

Castings may prove hard to machine due to a surface hardness that usually is occasioned by an unbalanced sulphur-manganese ratio, particularly when this condition is accompanied by too high a temperature of anneal, the condition being worse the higher the temperature becomes. Figs. 8 and 9 illustrate this condition. The

Fig. 9—Photograph with Very Low Magnification of a Piece Having a Hard Surface To Machine

Fig. 10—A Very Low-Magnification Photograph of a Casting Having a Deep and Thoroughly Decarbonized Surface Border That Was Very Soft and Consequently Developed Cutting-Hardness

same trouble can originate when the silicon, manganese and carbon contents are unduly low; or, what can be termed cutting hardness can obtain when the castings have undergone such a complete surface-decarbonization that the surface metal is hard to machine owing simply to its very softness that gums the tool and creates a friction that quickly draws the hardness of the tool cutting-edge. Fig. 10 illustrates this. In any and all such cases, and there are others that have not been mentioned that can cause surface hardness, the responsibility for the trouble lies entirely with the founder. I will endeavor to make clear that trouble from such occurrences soon will be a thing of the past.

Annealing-Oven Improvements

For the past 4 or 5 years a gradual improvement has been made in annealing-oven construction. Those who have had experience with the heat-treating of steel know the difficulties that obtain in an attempt to construct an oven of even small size so that the temperature at all parts can be kept uniform and under satisfactory control. It will be admitted, that the problem is increasingly difficult, the larger the oven is and, in the case of such large ovens as are required for the annealing of 30 to 60 tons of bulky castings, the difficulties are great. In spite of this, coal-burning ovens have been constructed that have proved to be surprisingly satisfactory, and the improvement in product is due in considerable measure to this fact. The electric oven for heat-treating is nothing short of ideal, but this proposition has been thought prohibitive in the case of very large ovens that must be under heat for at least 5 days. It is manifest that the bulk of current consumption during an anneal will take place in heating the oven and contents to the annealing temperature of 1525 and 1550 deg. fahr. With this fact in mind it was decided to construct an oven that would be insulated thoroughly, and designed so as to be heated by coal until the oven and its contents were at the proper temperature, the remainder of the anneal being accomplished by electrical heat under positive control. This

ı done and coal is used only in raising the oven :ontents to the annealing temperature. As soon ıas been attained, the current is turned onto the :e ribbons automatically, and from this time on : kept at a constant temperature through ther-c control, which is also used in lowering the tem- in accordance with the rate desired. Through ıcedure the annealing problem, that heretofore sioned more than considerable anxiety, has been d into a foolproof proposition that actually will 'e of itself automatically in every case. Even such an expedient it is still possible that some tings will be produced, but this can happen only vent that the castings charged in the oven are rect composition; but it will be shown later that ıibilities for occurrences of this kind are con-growing less.

the elimination of annealing troubles the indus- have taken its longest step forward, the impor- which should be plain to all. That I am justified tatement that the danger of faulty composition ight in the case of many of the plants, and that ity of product is very consistent and under good can be shown by consideration of the record of the plants. The performance is not confined to one or two, but is attained by a large number of them. It is true that not all of the plants have arrived at this point of excellence. This paper was prepared in part to illustrate briefly just what has been achieved in the way of progress and what may be expected in the natural course of events. Every difficulty that has been encountered has been fought to a finish insofar as money, time, hard work and available knowledge have made this possible; and as soon as it was felt that any particular problem was solved, work was started toward getting each plant in line. This procedure has been, and is, slow, but it is sure and, if the improvement thus far shown can be relied upon as indicating anything at all, the conclusion safely can be drawn that, with continual striving and persistent effort, the malleable iron casting should feature strongly in automotive construction.

TABLE 1—TEST DATA FROM 100 CONSECUTIVE HEATS

Plant	A	B	C	D
Ultimate-Strength, lb. per sq. in.	55,203	54,442	53,483	52,813
Elongation in 2 In., per cent	20.21	17.30	19.85	16.24
Best Bar Based on Ultimate-Strength				
Ultimate-Strength, lb. per sq. in.	60,678	59,500	57,397	56,900
Elongation in 2 In., per cent	27.50	19.00	28.90	17.00
Best Bar Based on Elongation				
Ultimate-Strength, lb. per sq. in.	58,180	57,000	55,833	53,800
Elongation in 2 In., per cent	31.50	28.10	31.50	27.00
Poorest Bar Based on Ultimate-Strength				
Ultimate-Strength, lb. per sq. in.	49,000	48,000	47,001	46,700
Elongation in 2 In., per cent	9.40	12.00	11.71	10.00
Poorest Bar Based on Elongation				
Ultimate-Strength, lb. per sq. in.	49,000	57,000	50,488	46,800
Elongation in 2 In., per cent	9.40	10.90	9.31	7.50

The records of 100 consecutive heats in the case of several of the different plants are tabulated in Table 1. It is believed that these data are sufficient to indicate at least that more than reasonable uniformity and efficient control are possible and practicable. While I trust that the points already covered will be looked upon as pertinent and of interest, I have not lost sight of the fact that what the engineer particularly desires to have is specific facts of such a character as will enable him to decide to what extent he will be justified in using the malleable-iron casting in the construction of his machine. It is realized also that he desires this information free from bias or misrepresentation.

Competing Materials for Casting

I am fully aware of the present shortcomings of the malleable-iron casting and of the materials that enter into competition with it. I know the latter as thoroughly as I believe I understand the shortcomings and merits of the product of which I am writing. In the case of one of the competitive products the serious difficulty is in connection with blowholes and poor machinability; in another case the fact that there may be unreliability because the finished article is but a very small part of a huge mass of metal in which segregation is possible and in which serious unsoundness not ascertainable except by the destructon of the part may be present and undiscoverable until failure takes place, is coupled with the difficulty of poor machinability; in a third product, which is an excellent one, the chief shortcoming is its limitation in regard to the form in which the article can be produced. These statements are set forth with but one idea in mind, to bring out the point, with which all are familiar, that in no case can any product be made perfect, nor does any single product possess all of the merits that are desirable. In the case of the three competitive products mentioned, all of which consist of steel, no doubt exists in the mind of the automobile engineer as to the fact that the metal per se is excellent in those cases where the composition is all right and structural imperfections absent. However, the source of supply is a matter that must be considered in connection with these products also, although I believe that at present this is not true to the extent that obtains in connection with the malleable-iron casting, for which reason, as has been pointed out previously, it is absolutely essential that this particular matter be given proper and painstaking consideration if these castings are to be used. It has been inferred that in the case of the three competitive products the engineer is fully satisfied with the metal from which they are made, because the metal is steel, and it is known that good steel is excellent, but the fact is often overlooked that the quality of steel, in common with all other products, may be inferior.

Physical Characteristics

Let us consider fully those physical characteristics of malleable iron with which the engineer is chiefly concerned. In Fig. 11 two different sets of curves are shown. The top curves cover ultimate-strength in pounds per square inch and the lower ones the percentage of elongation in 2 in. The broad line indicates in each case the requirements of the American Society for Testing Materials, and the curves above these show respectively the average ultimate-strength and the elongation of some 70 different plants. An inspection of these curves will demonstrate the fact that for nearly 4 years both the average ultimate-strength and the elongation of the bars of the plants referred to have been far in excess of the

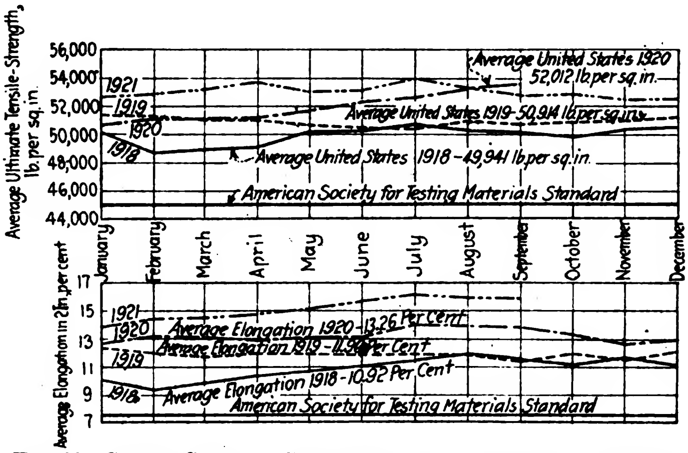


Fig. 11—Curves Giving a Comparison of the Average Ultimate-Strength and Elongation of the Castings Produced by Some 70 Malleable-Iron Foundries from Jan. 1, 1918, to Sept. 1, 1921, and the Requirements of the American Society for Testing Materials

American Society for Testing Materials requirements. The curves indicate also the healthy progress that has taken place from year to year under conditions that at times have been rather trying, in that frequently during this period it was impossible to secure the materials best suited to the process. For the past year the plants have not operated except at very low capacity, under which condition it is most difficult to operate with the ease that is possible when the plants are running at or near capacity.

While these curves apparently indicate truly the actual progress that has been made, what they show is misleading in that they are representative of the progress that has taken place among these plants with an increase in membership. A truer measure of progress could have been shown if the results of the original 20 or more plants that first formed the body in question had been plotted. The reason for this statement lies in the fact that the curves have been influenced continually by the taking in of new plants, the records of which at the start and for some time afterward obviously have served to lower the average record of the entire body. To present an accurate idea of what certain individual plants are doing and have done consistently for a long time, I will quote from my last report to this group of plants, which covers bars cast during the month of September, 1921.

TABLE 2—AVERAGE ULTIMATE-STRENGTH AND ELONGATION OF TEST BARS AT 14 PLANTS FOR SEPTEMBER, 1921

Plant	Ultimate-Strength, lb. per sq. in.	Elongation in 2 In., per cent
A	59,976	21.45
B	59,500	19.34
C	58,945	19.73
D	56,314	19.78
E	56,088	22.03
F	56,030	19.72
G	55,838	19.65
H	55,519	20.33
I	54,929	19.29
J	54,758	23.00
K	54,373	23.40
L	54,107	23.62
M	53,699	19.11
N	50,605	20.26

The average ultimate-strength and elongation, respectively, of 14 different plants for bars cast during this month are shown in Table 2. In this same month there were eight other plants in which the bars collectively

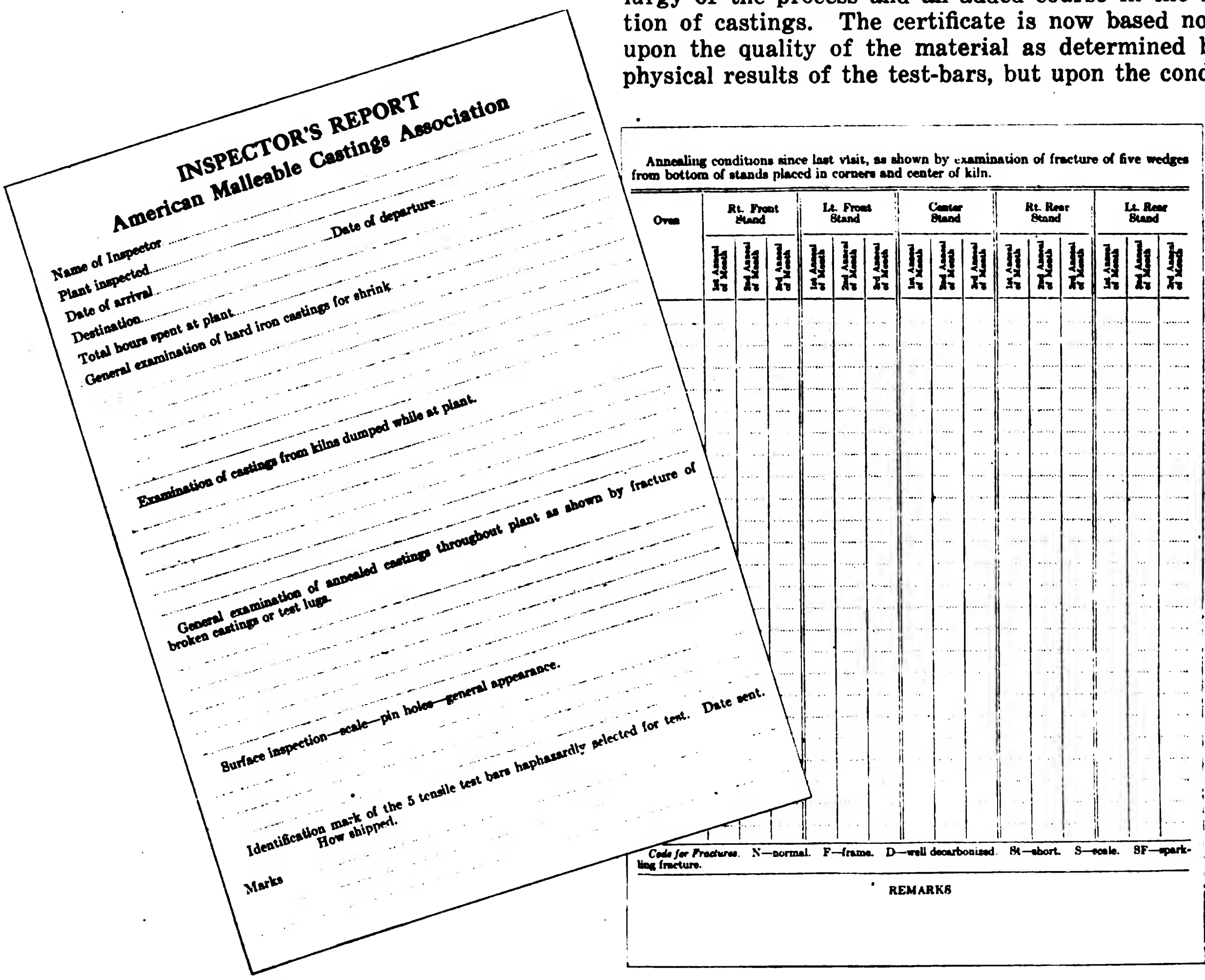
stood at average ultimate-strength of 55,137 lb. per sq. in. The lowest ultimate-strength in any case was 52,511 and the highest 57,774 lb. per sq. in.; in all cases, the elongation was slightly in excess of 18 per cent.

The foregoing data are furnished with the idea of presenting specific figures. These figures should remove any doubt in connection with the metal itself. Bars that run 30 per cent elongation are in no sense a surprise, and on different occasions we have had some that ran as high as 35 per cent. An accomplishment much more far-reaching and important is the fact mentioned previously that tests on bars from consecutive heats indicate that uniformity is now the rule and not the exception. Recent investigations indicate that we may hope for still further progress in this direction through the use of powdered coal for melting, a fuel that now has been adopted by a considerable number of the plants, owing to the ability of adjusting combustion and oxidation conditions with greater refinement. It is believed that, so far as uniformity is concerned, conditions will continue to improve. Remarks have already been made in connection with the annealing process and the steps that have been taken to safeguard this important end of the proposition.

Elimination of Shrinkage

While they are of prime importance, the concern of the producer of malleable-iron castings today is not in connection with uniformity and annealing, but is directed almost wholly to the matter of the elimination of shrinkage. Much has been learned as to the most efficient methods of gating and of heading the castings to insure soundness. The assistance of automotive engineers in this direction is needed and should be given unstintingly. Some automotive engineers may not be aware that it was decided several years ago to issue a certificate to those plants in which the test-bars for the month were equal to or better than the requirements of the specification of the American Society for Testing Materials. It soon was discovered that some of the members who were able to qualify in this connection were shipping castings that were defective owing chiefly to the presence of shrinkage, or that were hard to machine at high speed.

While the test-bar records of heats certainly have served a most useful purpose and are indispensable, it was seen clearly that the issuing of a certificate should be based not only upon the quality of the metal per se but that steps should be taken to put into force some method whereby the soundness of the casting could be assured, in order that the final granting of the certificate would be dependent upon the integrity of the castings as well. With this end in view it was decided to establish an inspection bureau that would form part of the engineer's office, the sole duty of which would be to send inspectors to the various plants to report to his office the exact conditions at each plant in regard to castings hard to machine and that contained shrinkage or other defects. Technically trained men were selected for this purpose, they having been given a special course in the metallurgy of the process and an added course in the inspection of castings. The certificate is now based not only upon the quality of the material as determined by the physical results of the test-bars, but upon the conditions


INSPECTOR'S REPORT
American Malleable Castings Association

Name of Inspector .... Date of departure ....
Plant inspected ....
Date of arrival ....
Destination ....
Total hours spent at plant ....
General examination of hard iron castings for shrink ....

Examination of castings from kilns dumped while at plant.

General examination of annealed castings throughout plant as shown by fracture of broken castings or test lugs.

Surface inspection—scale—pin holes—general appearance.

Identification mark of the 5 tensile test bars haphazardly selected for test. Date sent. How shipped.

Marks

Annealing conditions since last visit, as shown by examination of fracture of five wedges from bottom of stands placed in corners and center of kiln.

Oven	Rt. Front Stand			Lt. Front Stand			Center Stand			Rt. Rear Stand			Lt. Rear Stand		
	1st Anneal of Month	2nd Anneal of Month	3rd Anneal of Month	1st Anneal of Month	2nd Anneal of Month	3rd Anneal of Month	1st Anneal of Month	2nd Anneal of Month	3rd Anneal of Month	1st Anneal of Month	2nd Anneal of Month	3rd Anneal of Month	1st Anneal of Month	2nd Anneal of Month	3rd Anneal of Month

Code for Fractures. N—normal. F—frame. D—well decarbonized. St—short. S—scale. SF—sparkling fracture.

REMARKS

Fig. 12—Views of the Front and Back of an Inspector's Report Blank

at the plant in regard to the soundness and hardness of the castings.

The completeness with which the inspectors' work must be done can be gathered from Fig. 12 in which the obverse and reverse sides of the form which they are required to fill in are reproduced. I believe that the provisions contained in this inspection form cover the ground in a complete manner. If the castings of any plant are shown on one of these reports to contain shrinkage, not only is the matter taken up from this office but it is thoroughly ventilated at the plant itself. It can be conjectured that since the adoption of this procedure the quality of castings shipped has improved greatly. While this obviously has added somewhat to the cost of production, the sum, large as it is, is rather inconsequential as compared with the increased cost that has resulted through the attempt to eliminate shrinkage. Some time ago it was not unusual to obtain 75 per cent of castings from an air-furnace heat, whereas today in most of the plants referred to this figure is about 50 per cent, because of the large heads and risers used. Not only has the cost of remelting, extra cost for sand and the use of larger flasks been increased in consequence, but it is clear that air-furnace capacity has been lowered enormously.

Summary

In conclusion, the engineer need feel no anxiety in regard to the metal that enters the castings for, in this particular, there is absolutely no question whatever but that we have arrived. On the other hand, he should be very watchful in connection with such unsoundness as may result from shrinkage. The defects, if present, will be found generally where sections change abruptly from thin to thick; also at heavy bosses, where slight defects obviously will do absolutely no harm unless the boss is to be bored, when they will occasion much trouble in machining. Hard spots do not result from segregation, but from shrinkage. Blowholes, when present, are rarely if ever occasioned by occluded gases, and they are of rather infrequent occurrence due to any cause. There is only one case in which castings are hard to machine that the trouble has resulted from lack of annealing temperature or time at that temperature or from too rapid cooling, and this is when the casting is hard to machine throughout. In all other cases when castings are hard to machine, it will be found that the trouble is due to the presence of a more or less hard surface skin that may be produced in other ways than through lack of temperature during the anneal, lack of time at the annealing temperature or too quick cooling. It will be found that beneath this surface skin the metal is soft. This trouble, as previously pointed out, results in the greater number of cases from incorrect composition, the evil effect of which will be exaggerated by too high a temperature of anneal. At times, this trouble can result from a casing of the surface through a temporary pot atmosphere that is strongly reducing.

A deep and very soft decarbonized skin also can cause trouble in machining, due to its very softness. It is anticipated that all characters of machining trouble mentioned will disappear with the general installation of the electric annealing methods alluded to, although this in turn will result in an increased cost of production. It has been shown that little fear need be anticipated concerning a reasonable uniformity in physical properties of the metal from heat to heat.

Air-furnace construction and melting and the source of heat are being given every possible consideration. In a considerable number of the plants, carbon-dioxide recorders have been installed and if within a reasonable period it is found that this will contribute toward greater uniformity, these will be adopted generally.

First and foremost consideration should be given the source of supply. Be very suspicious of the plant that radically underbids another from which a satisfactory product has been received. Based upon prices, f.o.b. plant, there exists no royal road in the matters of cost of metal, molding and overhead for castings that are sound.

It is only through the exercise of the greatest ingenuity in molding practice and the use of much unnecessary metal that a sound casting can be produced from an incorrectly designed pattern. Even through the employment of the greatest molding skill available and the use of very heavy risers and heads, patterns are in existence from which no human being could obtain a sound casting, except perhaps at prohibitory cost. Cooperation can remedy this situation.

There exists no ferrous product having any ductility whatsoever that can be machined with anywhere near the speed of the malleable-iron casting. It is the cost of the finished and not of the raw casting that counts. Representatives of 70 different plants are meeting in all-day sessions every month to discuss possibilities of plant improvement and works practice. Other meetings are held incidentally. A large metallurgical engineering force is employed, well equipped chemical and physical laboratories are provided and money is lavishly expended in any direction that gives promise of improving works' practice in any direction. Research is continually in progress. It should be expected that, in the natural course of events, such serious and indefatigable work will result in a still greater improvement of the product.

BALLOON INSTRUMENTS AND METHODS

SOME of the instruments and methods used in piloting the balloon Aero Club of America in the last Gordon-Bennett race are described as follows in *Leslie's Weekly* by Ralph Upson, who piloted the balloon and won third place in the race, traveling a distance of 664 km. (412.59 miles)

Our only important instruments were an ordinary watch; a barograph for indicating and recording the altitude; a "feeler" for maintaining equilibrium; a "navigator" for obtaining horizontal direction and speed: and a "sounder" for investigating currents at other levels. The three last-named of these instruments were entirely original so far as I know, and were a wonderful help in handling the balloon, simply because they made our knowledge of its movements more reliable and exact. The feeler enabled us to get results with a minimum expenditure of ballast and gas, by indicating promptly any forces affecting our equilibrium. This instrument will undoubtedly become standard equipment for airships as well as free balloons. With the navigator we could quickly figure our actual direction and speed whenever we could see a stationary object below and knew our altitude above it.

The most important part of our sounding apparatus consisted of a small rubber balloon filled with hydrogen gas and let up on a string to a point 1000 ft. above the main balloon. Simple though it was in principle, it was made possible for the first time in this race owing to the discovery of a new type of "pilot-balloon," that held gas several hundred per cent better than any we had tried before.

CHROME-MOLYBDENUM-STEEL APPLICATIONS

(*Concluded from page* 50)

take on a given case-depth in 10 per cent less time than chrome-nickel steel; also, there will be a resultant average increase in Shore hardness of from five to seven points.

In spite of the fact that we have not received any complaints with regard to failures of case-hardened parts of chrome-molybdenum steel, and I feel assured we will not in the future, we have seen fit to discontinue this particular grade for this particular purpose. Chrome-nickel steel apparently still holds the first place among commercial steels for case-hardening of important parts, but it is the opinion that nickel-molybdenum steel will be a serious contender. At present we have a heat of approximately 100,000 lb. of nickel-molybdenum steel of the following analysis: Carbon 0.130, manganese 0.380, sulphur 0.022, phosphorus 0.020, nickel 1.580 and molybdenum 0.200. This material is being made into gears, knuckle-pins and the like. It is stated that this steel should prove a serious contender with chrome-nickel steel for case-hardening purposes, because of its ability, in the hot-rolled condition, to harden in oil after carbonizing. This statement may not be wholly clear to some, but it is a fact that a piece of hot-rolled steel of a given composition after carbonizing will not harden in oil to the degree that a piece of the same composition will if first subjected to forging.

The steering-knuckle pin has been one of our problems. This pin is made from ⅞-in. round hot-rolled stock and from alloy steel. It is case-hardened and a Shore hardness of 70 is required after final grinding. It always has been necessary to water-harden this piece, irrespective of the type of steel we use and, as a result, there is always a certain percentage of loss due to straightening. To illustrate, in one lot of 1949 nickel-molybdenum pins carbonized and hardened in oil, only 10 fell below 75 above hardness, none was lost in straightening or because of softness after final grinding. This we think is a remarkable record in view of the fact that chrome-nickel, chrome-vanadium, chrome-molybdenum and 3½-per cent nickel steels have all been tried without success.

To summarize this portion of the subject briefly, our observations lead us to believe that, for carbonizing purposes, chrome-molybdenum steels should prove entirely satisfactory for parts in which hardness alone is the chief factor, but should be considered carefully before being used for important parts in which combined toughness and hardness are requisite, such as gears, steering-knuckle pins and the like.

The results thus far obtained with nickel-molybdenum steel are very satisfactory in every way when compared with chrome-nickel steel, with the added advantage of the greater hardness that can be obtained from an alloy-steel of the former type.

There are many more details that could be added to the above, but I feel that they might serve to confuse rather than enlighten those desiring a frank statement of conditions pertaining to two important grades of chrome-molybdenum steel. In connection with the oil-hardening and spring steels we are at present in the midst of exhaustive investigation, but are not yet in a position to express an opinion.

THE ATOMS

AT present we have, I think, to accept it as a fact that the atoms consist of a positively charged nucleus of minute size, surrounded at a fairly respectful distance by the number of electrons requisite to maintain the structure electrically neutral. The nucleus contains all but about 1/2000 part of the mass of atom, and its electric charge is numerically equal to that of the negative electron multiplied by what is called the atomic number of the atom, the atomic number being the number that is obtained when the chemical elements are enumerated in the order of the atomic weights; thus hydrogen—1, helium—2, lithium—3, and so on. Consequently the number of external electrons in the atom is also equal to the atomic number.

The diameters of the nuclei of the atoms are comparable with 0.000000000001 cm. and the problem of finding what lies within the interior of such a structure seems at first sight almost hopeless. It is to this problem that Rutherford has addressed himself by the direct method of bombarding the nuclei of the different atoms with the equally minute high-velocity helium nuclei, alpha-particles, given off by any radioactive substances, and examining the tracks of any other particles that may be generated as a result of the impact. A careful and critical examination of the results shows that hydrogen nuclei are thus expelled from the nuclei of a number of atoms such as nitrogen and phosphorus. On the other hand, oxygen and carbon do not eject hydrogen under these circumstances, although there is ample and uncontrovertable evidence in the case of oxygen and nitrogen of the expulsion of other sub-nuclei, the precise nature of whose structure is a matter for further inquiry.

The artificial transmutation of the chemical elements is thus an established fact. The natural transmutation has, of course, been familiar for some years to students of radioactivity. The philosopher's stone, one of the alleged chimeras of the mediæval alchemists, is thus within our reach. But this is only part of the story. It appears that in some cases the kinetic energy of the ejected fragments is greater than that of the bombarding particles. This means that these bombardments are able to release the energy that is stored in the nuclei of atoms. Now, we know from the amount of heat liberated in radioactive disintegration that the amount of energy stored in the nuclei is of a higher order of magnitude altogether, some millions of times greater, in fact, than that generated by any chemical reaction such as the combustion of coal. In this comparison, of course, it is the amount of energy per unit mass of reacting or disintegrating matter that is under consideration. The amounts of energy that have thus far been released by artificial disintegration of the nuclei are in themselves small, but they are enormous in comparison with the minute amounts of matter affected. If these effects can be sufficiently intensified there appear to be two possibilities. Either they will prove uncontrollable, which would presumably spell the end of all things, or they will not. If they can be both intensified and controlled, then we shall have at our disposal an almost illimitable supply of power that will entirely transcend anything hitherto known. It is too early yet to say whether the necessary conditions are capable of being realized in practice.—Prof. O. W. Richardson, president, Mathematics and Physics Section of the British Association.

Bomb Dropping

A SUBMARINE is necessarily a very small target seen from the air, but not so cruisers and battleships and the resulting risk to the latter is so much the greater. To many persons, as an examination of the patent records makes abundantly clear, the problem of hitting a target is regarded as solved if the airman can manage to release his bomb at the moment he ascertains himself to be precisely over the target. In reality this is about the best way of making it absolutely certain that the bomb will miss its mark.

If an airman flies his machine on a steady course and at some given moment releases a bomb, he will notice that it remains vertically below him until such time as it strikes the sea, taking about ½ min. to fall from 10,000 ft. In other words, it will appear to him to fall in a vertical straight line. The effect of air resistance is small and not readily noticeable to the eye. But it must be recollected that this line, though vertical is not stationary but is moving with the airplane; hence a surface object that is in this vertical line at the moment of release will not be in the vertical from the aircraft at the later instant when the bomb reaches the sea level. In fact the distance apart of these two lines will be given by the product of the time of fall of the bomb by the speed of the airplane over the sea. With a time of fall of 30 sec. and a speed of 100 m.p.h. this distance is over ¾ miles; evidently therefore if the bomb is to hit the target it needs to be released 30 sec. before the aircraft reaches the point vertically over the target; and the aircraft must be pointed in precisely the right direction, or else the bomb will fall to the right or left of the target.

There are, then, two main errors to be guarded against; one due to releasing the bomb either too early or too late, and so either undershooting or overshooting the target, and the other due to the aircraft not pointing in precisely the correct direction, so that the bomb misses the target by falling to one side or the other. The former error can be guarded against by using a sighting device to indicate the precise moment for release, and the latter by the pilot paying close attention to the steering of the craft.

Design of Sights

An observer on the ground would not, perhaps, notice that the path of the bomb was one that must appear vertical as seen from the aircraft. Observing the motion of the bomb against a stationary background, he would describe its path as curved, in fact as parabolic. It is this parabolic path that to a ground observer, seems to make for complication in judging the correct moment for release; but any sighting device will be fixed to the aircraft and carried with it, so that for the devising of a suitable sight the important thing is the trajectory as seen from the aircraft and not as viewed from the ground.

In designing such a sight it is simplest to regard the motion of the bomb relative to the earth as made up of two components; the motion of the bomb relative to the aircraft, which is gradually increasing velocity in a vertical straight line, and the motion of the aircraft relative to the ground. The addition of these two by the usual triangle of velocities gives the motion of the bomb relative to the target, and if when the closing side of the triangle points at the target the bomb is released it

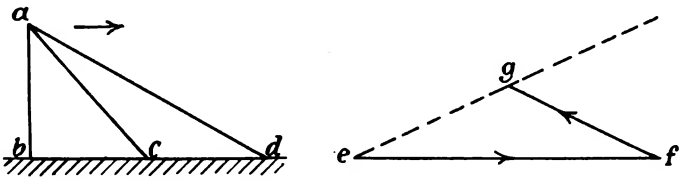


Diagram Showing the Relation between the Path of a Bombing Airplane, the Wind and Objects on the Ground

will hit the target, provided that the pilot is steering a correct course.

Estimation of Ground Speed

The average speed of the bomb relative to the aircraft is easily computed since it is always equal to four times the square root of the height measured in feet. Thus for a height of fall of 10,000 ft. the mean vertical velocity of the bomb is 400 ft. per sec. The velocity of the aircraft relative to the earth is more difficult to estimate. It is made up of two parts; its velocity relative to the air and the velocity of the air relative to the earth, which is, of course, the wind. If an aircraft is flying through the air at 100 m.p.h. and the wind has a velocity of, say 40 m.p.h. in the opposite direction, the speed of the aircraft over the ground which is commonly called the ground speed will be but 60 m.p.h. whereas if the wind were behind the airplane its ground speed would be 140 m.p.h. In the earlier days of bombing it was usual to drop bombs up-wind, occasionally to drop them down-wind, and never, intentionally, to attack across the wind. The speed through the air is given by the airspeed indicator, corrected so far as is necessary for the loss of air density with the altitude, but there is no dial on the aircraft that can give the velocity of the wind. On the other hand, it is possible by using a stop-watch to determine the ground speed by watching the rate of slipping away of the ground immediately below. For instance, it is easy to note the time taken for some ground object to pass from a point where it is 45 deg. ahead of the vertical to a point when it is directly below; in this time the aircraft must have moved a horizontal distance equal to its height, and, by dividing this by the time taken, a measure of the ground speed is at once obtained. Then with a knowledge of the ground speed and the mean vertical velocity of the bomb, the triangle of velocities can be set up in a linkwork, and an elementary form of bomb-sight provided. Such a sight would have its fore-sight moved along a horizontal scale of ground speeds and its back-sight along a vertical scale of altitudes, the distance being marked off to the square root of the altitude.

Simplified Methods

A most ingenious simplification of this procedure was introduced by Bourdillon in what was known as the C.F.S. sight. In this the distance timed over was not equal to the altitude, but was proportional to its square root. The arrangement can be shown algebraically to lead to two very useful results; one that no calculations need be made and the other that the back-sight can be left fixed and only the fore-sight need be moved. An almost contemporaneous invention was the equal-distance sight associated in England with the name of Scarff. In this a reversing stop-watch was used; at the first pressure

of the knob the watch hand started, at the second it reversed its direction, and at the third it sprang back to zero.

The diagram at the left of the accompanying illustration explains the procedure. Let *a* be an airplane flying over the ground, and let *b c* equal *c d*. Then if the stop-watch be started when some object on the ground is sighted along the line *a d* that is when the object bears at the angle *b a d* ahead of the vertical, and is reversed when the object has reached the point *c*, the watch hand will have exactly got back to zero by the time the ground object has reached *b*, the point vertically below the airplane. Now to hit the target the bomb must be dropped the same number of seconds before the target reaches *b* as it takes for the bomb to fall from *a* to *b*. Hence if a series of marks be put on the watch dial at times equal to the time of fall at various heights, the moment at which to release the bomb is when the reversed watch hand has come opposite the mark corresponding to the altitude of flight. Thus the moment to release is indicated by watching the watch, and not, as in the C.F.S. sight, by watching the target. This sight is of special advantage for use at sea, as it can be set by observations of the target itself even if, as frequently is the case, the latter is a ship under way. By sighting on the moving ship instead of on a fixed object on the earth the necessary allowance is automatically made for the ship's own motion.

Drift Bomb-Sights

Difficulty arises, however, in making careful observations in the excitement of an attack, and if it be desired to avoid altogether the use of a stop-watch, an alternative procedure is offered by the use of the drift bomb-sights developed by Wimperis. If an airplane be deliberately flown across the wind, the direction of the apparent drift of earth objects will be inclined to the fore-and-aft of the craft. This angle is called the angle of drift. Its amount is clearly proportional to the wind velocity; in fact, its tangent is given by the wind velocity divided by the air speed. A sight can therefore be devised in which, by setting a drift bar parallel to the earth drift when flying across wind, the foresights for up and down-wind bombing are automatically set to their true position and the actual velocity of the wind can be read off a scale. Equally, of course, if the velocity of the wind be given, it is possible to set the sight without any drift observations at all.

To bomb precisely up or down wind is, however, not so simple as it sounds. If, for example, an attempt at up-wind bombing be made, but the course chosen is somewhat inclined to the wind, the target will be missed. Thus if in the drawing at the right *e f* be the air speed and *f g* the wind, the airplane and the bomb will follow the line *e g* and not the line *e f*. Hence the bomb will fall much to the left of the target. A later modification of the drift bomb-sight provided for this by enabling the sight to be accurately set even when the flight path is not strictly parallel to the wind. Once this is done there is no need to bother to fly parallel to the wind. The airman is free to fly in any direction relative to the wind he pleases, and nevertheless the sight is always automatically set to the correct sighting position. This is especially of advantage when attacking moving targets, usually moving so as to make it intentionally difficult for the airman, and still more so when operating against disappearing targets like submarines, when there is no time to maneuver for up and down-wind positions, since the attack, if made at all, must be along the very shortest route to the target.

The art of bombing, complicated as it necessarily is by the great complexity and the variability of the factors that enter into it, is nevertheless one in which the use of uptodate sighting instruments affords the same sort of aid as modern gun-sights afford to naval gunnery. But the problem in the air tends to be the more troublesome to deal with by reason of the irregular, and sometimes violent motion of the relatively small craft in which the instruments are carried.—Engineering Supplement of *The Times* (London).

MECHANICAL INSPECTION IN EXPORT TRADE

After having spent several months in the foreign field as a traveling technical representative for an American motor-car company I feel that there is one matter in connection with automotive manufacturing applying to export products that can be better handled by the engineers, namely, mechanical inspection. In preparing these products for export, the fact that the cars may travel many thousand miles before they reach their destination and in this travel be subjected to conditions entirely foreign to any existing throughout our domestic territories must be given serious consideration. Upon arrival at destination, these cars are set-up by men who perhaps are not thoroughly competent, or lack the necessary equipment to do proper work. Therefore, it behooves American manufacturers to pay special attention to the inspection of goods destined for the export trade. Great care should be taken in the final inspection of engines, electrical apparatus, the clutch, the transmission and the rear axle, as these parts frequently arrive in the foreign field in defective condition.

Many times I have seen new engines torn-down that showed conclusively the abuse and carelessness of some final inspector at the factory, the connecting-rod bearings being loose and it being evident that the engine in its final block-test had been negligently handled and forwarded in bad condition. Electrical appliances arrive out-of-line due to improper mounting, and there are short-circuits that are, in the majority of cases, due to carelessness in wiring. In some instances generators and motors are affected by the change in climatic conditions. Such cases can be remedied only by close study and building to counteract the particular extraordinary conditions.

It is surprising to know that many cars are received with clutches out-of-line or not properly adjusted, involving a great amount of work by the foreign distributers. Transmissions and rear axles are a considerable source of trouble, their bearings being improperly fitted or the meshing of the gears being incorrect.

These conditions have, and if not obviated will continue to have, a marked adverse effect on the sale of American motor cars in foreign countries, as the foreign buyer does not accept excuses readily. Before the war he was more familiar with European cars that are carefully tried-out before shipment, such adjustments as are necessary being made at the factory instead of permitting the car to be forwarded and the chances taken of adjustment at destination under unfavorable conditions. The American motor car has gained great popularity in the foreign field, but to hold this favor, greater care must be exercised in final inspection, as our European competitors are taking advantage of each and every one of our errors.

My remarks do not apply to any one company, but to the automobile export-trade in general. The engineers should institute a far more rigid final inspection than has existed in the past in their respective factories.—Harry F. White.

Total Sensible Heats of Engine Fuels and Their Mixtures with Air

By ROBERT E. WILSON[1] AND DANIEL P. BARNARD, 4th[2]

Illustrated with DIAGRAM AND CHARTS

THIS article describes certain approximate methods used by the Research Laboratory of Applied Chemistry at the Massachusetts Institute of Technology in determining the total sensible heat content of Socony internal-combustion engine gasoline and kerosene and their mixtures with air at temperatures up to 500 deg. cent. (932 deg. fahr.). The resulting data are presented in such form as to make it readily possible to calculate, with sufficient accuracy for all practical purposes, the resultant temperature of an air-fuel mixture, knowing the temperature of the two constituents before mixing. Combined with the data on the dew-points of various fuel-air mixtures, this information is very valuable in determining the proper conditions for securing a completely vaporized mixture of air and fuel in various types of carbureter and heated manifolds. The results also indicate that the net effect of the compression stroke in an engine is to vaporize, rather than condense, the fuel and hence that the most difficult problem in connection with the vaporization of the fuel is to secure distribution.

A FEATURE that is of paramount importance to the efficient operation of an internal-combustion engine, especially of the high-speed type used in motor cars, is the securing of a uniform mixture of fuel and air in the proper proportions before distribution to the cylinders. The only reasonably practicable way of accomplishing this seems to be in having the fuel nearly, or preferably, completely vaporized. To vaporize present commercial gasoline or any less volatile fuels completely, it is necessary to add some heat from external sources.[3] It is possible to secure satisfactory vaporization by any one or more of three methods, which may be classed as follows:

(1) Atomization of cold fuel into heated air
(2) Atomization of cold fuel into cold air followed by heating the resulting mixture in the manifold. The "hot-spot" aids vaporization partly by heating the mixture as a whole, but to a greater extent by throwing the uncondensed drops onto the heated manifold surface and vaporizing the liquid directly
(3) Injection of the fuel as a superheated vapor into cold air

The first two methods are frequently combined in the use of the hot-spot in conjunction with a preheater. These methods suffer from a fundamental defect in that it has been found necessary to superheat the air or mixture considerably above its theoretical dew-point in order to vaporize the fuel completely in the short time available. This results in a decreased volumetric efficiency coupled with an increased tendency toward knocking. The last method, however, starts from the other side of equilibrium and therefore is theoretically the best means of securing the proper mixture, as it is necessary to heat the vaporized fuel only to such a temperature that the resulting mixture will be approximately at the dew-point. Indeed, experimental results in this laboratory and elsewhere have shown that the mixture prepared by this method may be as much as 30 to 35 per cent condensed before the distribution is seriously affected, even in a poorly designed manifold, because the extremely small particles formed by the rapid condensation of the superheated vapor do not tend to separate readily from the air-stream. The particles then produced are, at least for the first few moments after condensation begins, far smaller than those obtained by the best methods of atomizing a liquid.

The practical application of the third method requires fairly accurate data on two subjects; (*a*) the dew-points of various fuel-air mixtures; and (*b*) the specific heats, or rather, the total sensible heats, of the fuels at high temperatures. The data on dew-points have been covered in the article previously mentioned. It is the purpose of this article, therefore, to cover only the subject of specific and total sensible heats.

A survey of the available literature failed to yield any data on specific heats of paraffin hydrocarbons at the high temperatures required. Practically the only work done along these lines indicated that up to 100 deg. cent. (212 deg. fahr.) the specific heat, averaged for a large number of petroleum distillates in the liquid state, could be represented with a fair degree of accuracy by the equation modified from Bushong and Knight[4]

$$C_p = 0.5000 + 0.0008\,t$$

where

C_p = specific heat at constant pressure
t = temperature in degrees centigrade

Other data[5] indicate that the specific heat at room temperature of light petroleum distillates is very close to 0.5. Such data as are available indicate, as do the vapor-pressure curves, that the specific heats of the liquid and the vapor are substantially equal over the temperature range involved.

While the existing data on the heats of vaporization of hydrocarbons are variable, as is shown in Table 1, it is nevertheless possible by combining these data with Trouton's rule that the heat in calories required to vaporize one molecular weight in grams of a non-associated liquid is equal to 20.5 times the temperature of the boiling point in degrees centigrade absolute, which is known to hold quite well for hydrocarbons, to derive fairly satisfactory values for gasoline and kerosene.

For this work, the best values for the heats of vaporization were chosen as 60 calories per gram for Socony kerosene, the average boiling point of which corresponds to dodecane, and 70 calories per gram for Socony gasoline, the average boiling point of which corresponds to octane. These figures represent a sufficiently good approximation for present purposes.

---

[1] Director research laboratory of applied chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Research associate, Massachusetts Institute of Technology, Cambridge, Mass.

[3] A discussion of this subject will be found in a paper by the authors entitled Condensation Temperatures of Gasoline and Kerosene-Air Mixtures, which was published in THE JOURNAL, November, 1921, p. 813.

[4] See *Journal of Industrial and Engineering Chemistry*, vol. 12, p. 1197.

[5] See *American Chemical Journal*, vol. 28, p. 66; *Journal of Industrial and Engineering Chemistry*, vol. 6, p. 727, and *Zeitschrift für Angewandte Chemie*, vol. 12, p. 621.

TABLE 1—HEATS OF VAPORIZATION OF HYDROCARBONS IN CALORIES PER GRAM

Hexane C_6H_{14}	Heptane C_7H_{16}	Octane C_8H_{18}	Nonane C_9H_{20}	Decane $C_{10}H_{22}$	Undecane $C_{11}H_{24}$	Dodecane $C_{12}H_{26}$	Source
79.4	74.1	71.1		60.8			Maybery & Goldstein
		63.54	63.1	62.0		60.0	Syniewski
	74.0					60.0	Ricardo
81.6	74.5	71.5	67.5	64.5	61.4	59.0	Trouton's Rule
		65.3				60.5	Wilson and Barnard[a]

[a] From slopes of vapor-pressure curves in paper entitled Condensation Temperatures of Gasoline and Kerosene-Air Mixtures.

On account of the paucity of data at the higher temperatures, our laboratory undertook to make some approximate experimental determinations of total sensible heats of two typical internal-combustion engine fuels up to about 500 deg. cent. (932 deg. fahr.). The experimental method used in securing these data was

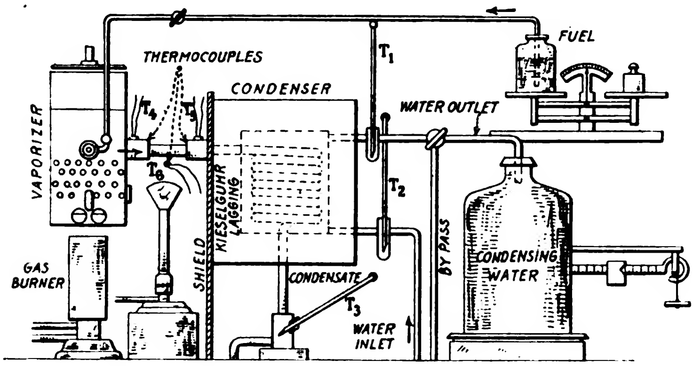


FIG. 1—APPARATUS EMPLOYED IN DETERMINING THE SENSIBLE HEATS OF VAPORIZED FUEL

probably not accurate to closer than 3 or 4 per cent, but is sufficiently near to the truth for all practical work, especially in view of the rather indefinite composition of the materials investigated. The publication of the data appears worth while in view of the practical importance of the subject and the complete lack of any similar data in the literature.

EXPERIMENTAL WORK

The experimental work was confined to two fuels, Socony kerosene and Socony gasoline. The gravity of the kerosene was 45 deg. Baumé, corresponding to a specific gravity of 0.800; and that of the gasoline was 60 deg. Baumé, corresponding to a specific gravity of 0.743.

The total heats of these fuels were determined at various temperatures in the apparatus shown in Fig. 1. The distillate from the vaporizer, which was heated by a gas blast burner, was continuously condensed in a water-cooled steel coil. The condenser was tightly lagged with about 2 in. of kieselguhr and the temperatures of the inflowing and outflowing cooling water were read from the thermometers T_1 and T_2. The cooling water was caught and weighed for each run. The weight of the cooling water multiplied by the difference in the temperatures T_1 and T_2 equals the heat given up by the fuel in cooling to the discharge temperature, T_3. The thermometers T_1 and T_2 were checked against each other, and showed no deviation over the range of temperatures involved. The vapor temperatures were measured by thermocouples placed at T_4 and T_5, and the air temperature around the vapor pipe, indicated by the thermocouple T_6, was kept slightly above that of the vapor to prevent more

TABLE 2—RESULTS OBTAINED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Specific Heat Data

Fuel	Run	Length of Run, min.	Heat Loss Correction	Determined	Corrected	$Q - r$	Temperature deg. cent.	Temperature deg. fahr.	r
Kerosene	1	12	24	336	360	300	460	860.0	60
Kerosene	2	12	24	317	341	281	461	861.8	60
Kerosene	3	12	24	317	341	281	459	858.2	60
Kerosene	4	12	24	321	345	285	461	861.8	60
Kerosene	5	10	20	265	285	225	375	707.0	60
Kerosene	6	10	20	270	290	230	375	707.0	60
Kerosene	7	10.	20	262	282	222	365	687.0	60
Kerosene	8	8	16	239	255	195	327	620.6	60
Kerosene	9	8	16	233	249	189	318	604.4	60
Kerosene	10	8	16	236	252	192	314	597.2	60
Gasoline	11	14	28	308	336	266	446	834.8	70
Gasoline	12	14	28	300	328	258	434	813.2	70
Gasoline	13	14	28	265	293	223	376	708.8	70
Gasoline	14	12	24	242	266	196	338	640.4	70
Gasoline	15	12	24	227	251	181	338	640.4	70
Gasoline	16	12	24	235	259	189	340	644.0	70
Gasoline	17	12	24	230	254	184	328	622.4	70
Gasoline	18	8	16	202	218	148	290	554.0	70
Gasoline	19	8	16	200	216	146	289	552.2	70
Kerosene	20	8	16	219	235	175	308	586.4	60
Kerosene	21	8	16	230	246	186	308	586.4	60
Kerosene	22	8	16	220	236	176	300	572.0	60
Water	23	20	40	756	797[7]	...	434	813.2	..
Water	24	20	40	757	798[7]	...	440	824.0	..

[7] From Marks and Davis Steam Tables h at 434 deg. cent. (813.2 deg. fahr.) = 1433 ÷ 1.8 = 797 calories. The difference between the observed value and that given above = 798 — 757 = 41 calories loss by radiation, etc., per gram of fuel in 20 min.

than minor heat losses. A variation of 75 to 100 deg. cent. (167 to 212 deg. fahr.) in the air temperature produced no appreciable change in the vapor temperatures.

In making the determinations, the apparatus was allowed to run until substantially constant temperatures had been maintained at all points for at least 10 min. The time was then noted and the condensing water caught while 500 grams of fuel passed through the generator, readings being taken frequently to check the temperatures. All runs were discarded in which the water temperatures varied over 1.0 deg. cent. (1.8 deg. fahr.) In most cases the variation was less than 0.5 deg. cent. (0.9 deg. fahr.) Several check runs were made at each temperature, the results of which are indicated in Fig. 2.

Since the condenser was admittedly not adiabatic, it seemed desirable to determine approximate figures for the heat losses and other correction factors by passing water through the generator and condenser, and comparing the total heat of the steam as thus determined with the values given in Marks and Davis Steam Tables. The results were found to be 41 calories per gram too low for 500 grams of water vaporized over a period of 20 min. The heat losses were therefore assumed to be 2 calories per gram per min., and the results of the other deter-

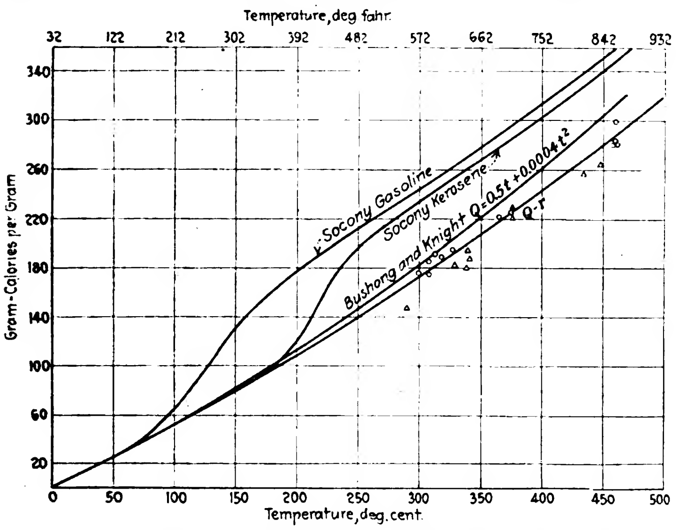


FIG. 2—THE SENSIBLE HEAT CURVES OF KEROSENE AND GASOLINE

minations were subjected to this correction which remains constant for all determinations, as the *same* weight of fuel was passed through in each case.

RESULTS

The experimental results as obtained by the foregoing procedure are recorded in Table 2. The total sensible heats have all been corrected to 0 deg. cent. (32 deg. fahr.)

It is very desirable to tie in these high-temperature data with the values given in the literature for the specific heats of these hydrocarbons in the liquid state. This cannot be done directly, but by subtracting the value of r, the heat of vaporization of the fuel in question, from the observed figures for the total sensible heat at high temperatures, values can be obtained that should lie on a smooth curve with the data for the sensible heat of the liquids at temperatures below the boiling point. This method of treatment of the results is, of course, rigidly applicable only in cases where the heat of vaporization is substantially constant over the temperature range in question, and hence the specific heats of the liquid and the

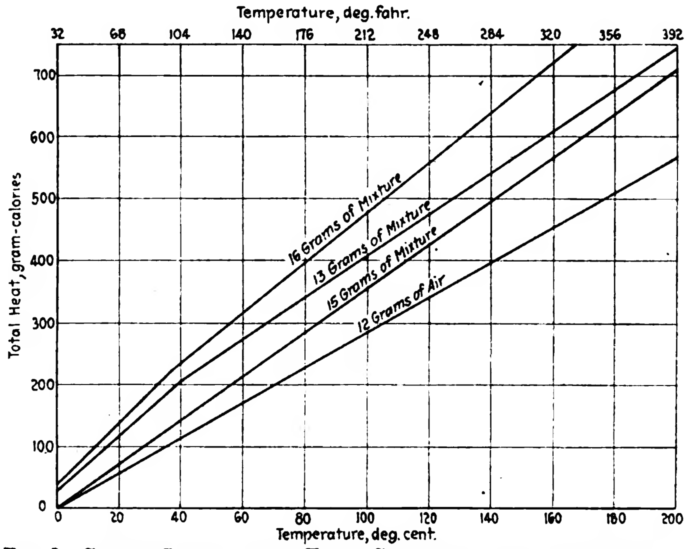


FIG. 3—CURVES SHOWING THE TOTAL SENSIBLE HEATS OF KEROSENE-AIR MIXTURES

vapor are equal at a given temperature. That this is substantially true for the paraffin hydrocarbons in question is indicated both by data in the literature and by the fact, discussed in the article on condensation temperatures, that the vapor-pressure data obtained for these fuels gave straight lines when log p was plotted against $1/T$.

The values thus obtained are presented in column seven of Table 2, and graphically in Fig. 2. For comparative purposes a line is drawn to represent the extrapolation of the recent data of Bushong and Knight[8] which was obtained from specific-heat measurements on light petroleum distillate, liquid only, at temperatures up to 100 deg. cent. (212 deg. fahr.). It will be noted that the agreement is not bad considering the unjustifiable extrapolation of Bushong and Knight's equation

$$C_p = 0.5000 + 0.0008\,t$$

where

$C_p =$ specific heat at constant pressure
$t =$ temperature in degrees centigrade

The best representative line for the points determined in this Laboratory lies below the curve of Bushong and Knight and accords best with the equation

$$C_p = 0.5000 + 0.0006\,t$$

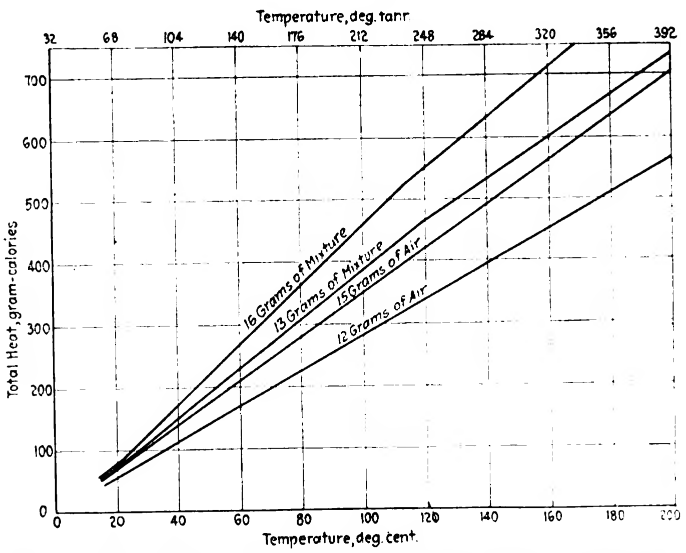


FIG. 4—TOTAL SENSIBLE HEAT CURVES FOR MIXTURES OF GASOLINE AND AIR

[8] See *Journal of Industrial and Engineering Chemistry*, vol. 12, p. 1197.

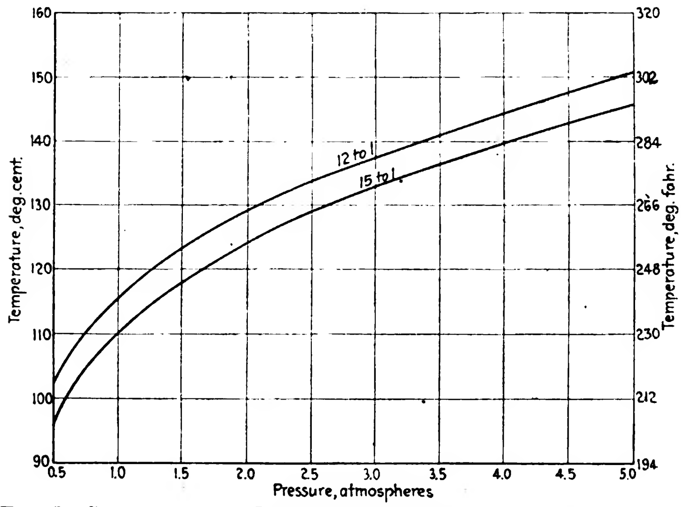


FIG. 5—CURVES OF THE INITIAL CONDENSATION TEMPERATURES OF KEROSENE-AIR MIXTURES HAVING DIFFERENT RATIOS

It will be noted that values obtained for gasoline lie, on the average, about 5 calories below the $Q - r$ points for kerosene. This discrepancy, which is in the opposite direction from what might be expected, is possibly due to the assumption of too large a value for the heat of vaporization for the gasoline. The value obtained from the slope of the vapor-pressure curve of the identical fuel was, as indicated in Table 2, 65.3 calories per gram, but a value of 70 was assumed in determining $Q - r$ because it accorded better with other data in the literature.

Assuming, however, that the line $Q - r$ is correct as drawn for both fuels, since the divergence is just about within the limit of error of the method, it is then possible to add to this line the fractional amount of the heat of vaporization that corresponds to the fractional amount of the fuel which is vaporized at any given temperature. This was the method used in obtaining the curved lines shown in Fig. 2, which represent within a probable error of 3 or 4 per cent the values for the total sensible heat of gasoline and of kerosene as a function of temperature at a pressure of one atmosphere.

Figs. 3 and 4 give respectively the sensible heats of kerosene-air and gasoline-air mixtures. The heats are given in gram calories for 13 and 16 grams of mixture, and also for 12 and 15 grams of air. The heat content of air was calculated from the equation[9]

$$29\,H = 6.5\,[T - 273] + 0.0005\,[T^2 - (273)^2]$$

where

H = heat in calories per gram

T = temperature in degrees Kelvin or the temperature in degrees centigrade plus 273

These curves make it possible to read the temperature of the resulting air-fuel mixture directly if the initial temperatures of the air and the fuel are known. If, for example, kerosene enters the mixing chambers at a temperature of 400 deg. cent. (752 deg. fahr.), and the air is at 50 deg. cent. (122 deg. fahr.), then the total heat of 16 grams of a 15 to 1 mixture is equal to 304 + 175, or 479 calories. The final temperature of the resulting mixture corresponding to this heat content is 104 deg. cent. (219.2 deg. fahr.) By such calculations it is possible to determine exactly how hot the air or fuel should be heated before mixing in order to give a dry gas mixture at equilibrium, or indeed to determine any one of the three temperatures if the other two are known.

In this connection, there has been considerable speculation as to what happens with regard to the condensation or evaporation of the fuel during the compression cycle of an Otto cycle engine. The increase in the pressure taken by itself would, of course, tend to cause condensation, but the heat liberated during the compression would raise the temperature of the mixture and tend to evaporate any uncondensed fuel. Without accurate data as to the change of the vapor pressure with the temperature and the sensible heat of a given fuel, it was impossible to give a definite answer to these questions, but from data presented in this and in our previous paper definite conclusions can be drawn as follows:

> Making the calculations on a 5 to 1 compression ratio for Socony kerosene and assuming that the value of the exponent in the equation $pv^k = $ a constant for the compression is 1.2, which makes a maximum allowance for cooling during compression, it can be shown readily that the tendency of the compression as a whole is to vaporize rather than condense the fuel, and indeed, that theoretically it would be possible to vaporize by compression a mixture of kerosene and air which was initially 75 per cent condensed. Actually, of course, the time would probably be insufficient to vaporize this amount of material, but it seems certain that if the mixture is near enough to complete vaporization as to give proper distribution, there will be very few, if any, liquid drops present at the moment of ignition, and that the fuel will, under no circumstances, condense out during compression.

[9] See General Principles of Chemistry by Noyes and Sherrill.

SERVICE

IF the maximum value to the user with the minimum service-cost to the manufacturer is to be attained, the future changes in our products must be in the direction of eliminating needless varieties in design and toward the selection of the best types of construction. The elimination of needless variety is necessary to reduction of both production costs and service costs for two reasons

(1) Quality of workmanship and material are more easily maintained as the variations in mechanical practice are decreased

(2) Incompetence of the service workman can be more effectively reduced as the variations in mechanical practice decrease

It necessarily follows that future changes in automotive products should not only lead toward the elimination of needless variety, but the maintenance of the needed variety and the correct use of these variances with respect to more intelligent marketing policies. The success of a company is primarily dependent upon the adequacy of its sales and service. There should be a more equitable working arrangement between these two most important phases of the industry.

If the retail service-station has been inefficient, it is we who are to blame. There is a total of 45,135 automobile repair shops in the United States. It stands to reason that the individuals operating these repair shops do not have the same opportunities to develop proper methods of servicing our products as do we. We must begin to take greater advantage of our facilities and give our dealers the advantage of our best experience. Efficiency is responsibility met. We have not met our service responsibility until we place repair parts within immediate reach of our car owners, even in the most remote sections of this country. All other things being equal, the usefulness of any automotive product is inversely proportional to the time lost on account of repairs.

The automotive industry leads all others in the fields of scientific research, invention, engineering, processing and manufacturing. The efficiencies and economies exercised in our modern plants are the standards of the world, but the injection of similar standards and efficiencies into our marketing and servicing methods is yet to be accomplished.—Norval A. Hawkins.

Current Standardization Work

Although the definite recommendations of the Divisions of the Standards Committee were published in the December issue of The Journal, many other subjects are being actively considered by Subdivisions, as is indicated hereinafter, with a view to submitting reports at the Division meetings to be held during the coming year. As soon as the Standards Committee personnel for 1922 is appointed by the Council, tentative Division meeting schedules will be determined upon and announced so that committee members can plan to take care of business as well as standardization matters on any trips necessitated in attending the Division meetings.

Bases, Sockets and Connectors

The Lighting Division is considering a proposal that the tolerances for the diameters of the standard bases and sockets for head-lamp bulbs should be reduced, as it is stated that they are wider than necessary and permit sufficient play to cause considerable variation in the position of the filament and consequently the illumination characteristics of the lamps. It is felt that although narrower limits are not essential, they would improve the specifications and not introduce undue restriction on manufacturers of the parts.

Brake-Lining

A meeting of the Subdivision on Brake-Lining was held in October in New York City, F. C. Stanley, of the Raybestos Co., G. W. Skirm, of the United & Globe Rubber Co., W. D. Pardoe, of the Thermoid Rubber Co., C. Bockius, of the Manhattan Rubber Mfg. Co., R. H. Soulis, of the Multibestos Co., and C. Carsson, formerly with Johns-Manville, Inc., being present. All of the companies represented at the meeting having had in operation brake-lining testing machines similar to the one being used at the Bureau of Standards, there was a general discussion of the machine. It was stated that some trouble had been experienced in getting the apparatus to function satisfactorily, apparently on account of minor manufacturing defects and the fact that there had not been sufficient time to get the machines adjusted and running properly. A discussion of the method of testing seemed to indicate general approval of the use of this machine when run at 600 r.p.m. without water-cooling with a load of 6 hp.

It is felt that some supplementary test must be developed which will approximate the temperature conditions and unit pressure encountered on a passenger car in the ordinary intermittent service application of brakes. No definite outline of this test was reached at the meeting.

It was agreed that a quantity of folded and stitched lining and a like quantity of woven lining, none of the material being confined to that made by any one company, would be purchased and 6 ft. of each type of lining tested by the companies represented with the machines operating under similar conditions. The results, including those of the Bureau of Standards, will be compared to find out what degree of uniformity shall have been obtained, this being the next step toward developing a standard specification.

Breaker Contacts

At the last meeting of the Electrical Equipment Division it was decided to consider the standardization of the hexagon stock used in making timer-distributor contact-breakers. It was stated that there is considerable variation in the size of stock used for mounting the breaker-points, necessitating a number of sizes of wrench for adjusting this part on the several types of ignition apparatus.

It was suggested that ¼-in. hexagon stock be considered for adoption as standard, and that if this is not feasible, the standard should embody a range of two or possibly three sizes such as 3/16, ¼ and 5/16-in. It was argued also that the proposed standard should embody the height of the hexagon and the size and length of the thread. Information on present practice is to be obtained for consideration at the next meeting of the Division.

Door-Handles

At the last meeting of the Passenger-Car Body Division it was reported that investigation showed that a center-to-center distance of 1½ in. between escutcheon-plate screws was very common. As the standardization of door-handle-square bearing diameters was suggested, it was decided to continue the investigation. The subject was assigned for further consideration to G. E. Goddard, who will make an investigation covering escutcheon-plates, door-handle-square bearings and the bevel on door lock-bars and escutcheon-plate screw sizes.

Door-Hinges

Discussion of this subject indicated that it may be possible to standardize some features of exposed hinges, the following dimensions being submitted as desirable practice.

Type	Plate Width, in.	Thickness, in.	Screws No. Size
Malleable or Forged	1¾	3/16	4 No. 10
	2	1/4	4 No. 12
Pressed	2	1/8	4 No. 12

Clearance between plates shall be 1/16 in. at the exposed end, tapering to ⅛ in. at the concealed end when hinges are closed.

As it was advocated that hinge-pin diameters, hinge offsets and possibly hinge projections be standardized, it was decided to give this subject further consideration. E. G. Simpson was appointed a Subdivision of one to secure the necessary data and prepare a tentative recommendation.

Electrical Equipment Nomenclature

The use of the term "Timer-Distributor" was thoroughly discussed at the Standards Committee Meeting held on May 24, 1921, and several negative votes were cast against the adoption of the term by members of the Society in the July 1921 Society Letter Ballot on the adoption of standards. The comments submitted were discussed at the Oct. 17 meeting of the Electrical Equipment Division and the opinion was expressed that "Timer-Distributor" is the most suitable term and should be retained. Chairman Libby stated that he had noticed that the term is used in the majority of cases in technical references and in about 80 per cent of the patent investigations that he has conducted, and that these sources indicate that the term is of long standing. It was therefore decided to recommend no change in the present nomenclature.

Generator Mountings

At the last meeting of the Electrical Equipment Division T. L. Lee, chairman of the Generator and Starting Motor Subdivision, reported that, after studying the suggestion to omit the dimensions for the pilot specified in the present Standard for Generator Flange Mountings, he did not consider it advisable to do so. The discussion indicated that although one large manufacturer of electrical equipment, which suggested omitting the pilot dimensions, does not use pilots on its equipment, a large number of other manufacturers do. The advantage of retaining the pilot was pointed out and the statement made that when a customer orders equipment on which no pilot is desired, it is easy to machine off the pilot.

A suggestion in reference to lengthening the threaded-end of the shaft of the Generator Bracket Moulding was discussed at length and the decision reached that a change is not desirable owing to the limited space provided for the couplings, particularly in present engine designs.

The Subdivision was assigned the work of standardizing a strap mounting for generators. This had been suggested by an automobile builder, it being stated that a standard should specify a generator barrel-diameter of a sufficient distance along the barrel to give a stable mounting, with tolerances of possibly plus or minus 0.002 in. applying to the diameter. It was also said that a standard should establish certain limits for the concentricity between the finished part of the barrel and the armature shaft.

Lubricating Oils

The Lubricants Division is formulating definite specifications for lubricating oils for use in internal-combustion engines with the exception of aircraft and Diesel engines. The specifications tentatively outlined follow in general the specifications of the American Society for Testing Materials and those given in the Bureau of Mines' Bulletin No. 5 in accordance with recommendations of the Interdepartmental Committee on Standardization of Petroleum Specifications.

At a recent meeting of the Division it was stated that compounded or blended oils are being used by a number of engine builders, due partly to their successful use in Europe, and that acidless tallow and castorated oils are used to some extent. Discussion as to what kinds of oils should be taken into consideration in formulating specifications led to the decision to confine the recommendations to straight mineral oils. It was thought that if specifications for blended oils are desirable, they can be developed after the Division shall have had an opportunity to obtain more information as to their use.

Magnet Wire

At the last meeting of the Electrical Equipment Division it was decided to take up the standardization of magnet wire for automotive apparatus, including both fabric and enamel insulation types. A. D. T. Libby, chairman of the Division, has appointed a Subdivision to prepare a tentative specification. It was the consensus of opinion that the specifications for the copper wire should conform with Specification No. B3-15 of the American Society for Testing Materials and that all wire sizes should be drawn to the American wire gage.

Metric Roller Bearings

At the meeting of the Ball and Roller Bearings Division held on Oct. 11, 1921, it was voted to request the Subdivision on Roller Bearings to continue consideration of the following revisions of the present S.A.E. Standards for Roller Bearings, proposed by the Subdivision on Nov. 20, 1918, as it was felt by those present that the demand for standard metric roller-bearing sizes that are interchangeable with the wide or double-row type ball bearings is becoming greater. It was stated at the meeting that the present dimensions of the standard metric roller-bearings are generally considered very satisfactory, although possibly a few changes in tolerances, overall widths and corner radii should be made. All members present were of the opinion that these standards should be put into the best form possible.

Bearing Numbers—Bearings of the light series shall be designated by prefixing the letter *L*, the numbers ranging from L04 to L22 consecutively, and bearings of the medium series by prefixing the letter *M*, the numbers ranging from M04 to M22 consecutively

Inside and Outside Diameters—The inside and outside diameters shall be given in integral millimeters and shall correspond to the inside and outside diameters for the same sizes of the annular ball bearing of the light and medium series, pages C26 and C28, S.A.E. Handbook

Widths—The widths shall be given in inches and shall be in accord with the widths of the annular ball bearings of the wide type, page C31, S.A.E. Handbook

New Sizes—The medium series shall be extended to specify dimensions for bearings Nos. M21 and M22; the inside diameter for bearing No. M21 to be 105 mm., the outside diameter 225 mm., and the width 3 7/16 in.; and the inside diameter for bearing No. M22 to be 110 mm., the outside diameter 240 mm. and the width 3⅝ in.

Chamfers—The chamfer or radius on the inner and outer races of bearings of the light and medium series with inside diameters from 20 to 25 mm. shall be 1 to 1½ mm.; for inside diameters from 30 to 50 mm., the chamfer shall be from 2 to 4 mm.; and for inside diameters from 55 to 110 mm., the chamfers shall be from 3 to 5 mm. The headings of the columns in the tables giving the chamfers shall read "Radius or Chamfer C" and the limits shall be shown as maximum and minimum

Clearances—The maximum clearances required for the bearing cage, when used, shall be given for each size of bearing. These clearances shall not be considered as standard, but as general information only

Eccentricity Tolerances—Further consideration shall be given to the question of whether the eccentricity tolerances given in the present S.A.E. Standards refer to the error in running truth actually measured or to the true eccentricity of the center of the inner and outer races

Diameter Tolerances—Further consideration shall be given to the tolerances for the diameter, as these depend upon the type of bearing and its application

Motor-Truck Cabs

It has been requested that the Truck Division standardize the mounting dimensions for motor-truck cabs so as to permit interchangeability. This matter has been referred to the members of the Truck Division. If it should be the general opinion of the Division that this subject should be taken up, a Subdivision will be appointed to formulate a tentative recommendation.

Oil-Drain Plugs

At the last meeting of the Engine Division the desirability of providing suitable means for easily draining all engine oil-pans was discussed. It was decided that, as the oil-drain is a part that is dependent upon individual engine design, no definite type should be standardized, but that a recommendation could be formulated which would indicate that an oil-drain device should be provided, having a hole of a minimum size located at the lowest part of the oil-pan or crank-case cover. In order that the Engine Division may base its recommendation on the best present-day practice, a questionnaire covering these points has been sent to engine builders and automobile producers who build their own engines.

Silent Chains

At the last meeting of the Chain Division, held jointly with the Committee on Steel Roller Chains of the American Society of Mechanical Engineers and the Committee on Sprockets of the American Gear Manufacturers Association, the subject of silent-chain standardization was brought up, but it was the consensus of opinion that structural differences between makes prevent the adoption of a standard at the present time. It was thought that normal silent-chain development during the next few years will make standardization possible.

It was stated that to obtain interchangeability of silent chains it will be necessary to standardize the pitch, the included angle, the method of guiding, the width, the maximum radial clearance from the joint over the back of the link, the maximum distance from the center of articulation to the point of the link, the perpendicular distance from the bearing face of the link to the center of articulation and the location of the top of the teeth with regard to the chord connecting the centers of articulation. It was emphasized that

the standardization of silent chains is further complicated owing to the actual differences in construction of the chains.

Spark-Plug Hoods

At the last Electrical Equipment Division meeting it was reported that a thorough investigation of the patent situation in connection with spark-plug hoods had been made and that it was claimed that a number of patents in the aggregate cover any practical form of construction. It was therefore decided to discontinue consideration of the standardization of spark-plug hoods.

Storage Batteries

It has been felt that the Standards Committee could be of service to the storage-battery and associated industries in connection with the recent development of a molded hard-rubber storage-battery container. As the molds and equipment for making these containers are very expensive, it seems that the logical procedure for the battery, automobile and hard-rubber manufacturers is to get together and adopt standards relating to the rubber container, before too much money shall have been spent on mold and machine equipment.

A further object of the standardization proposed would be perhaps to guide the automobile builders in adapting their battery compartments to this more compact type of battery,

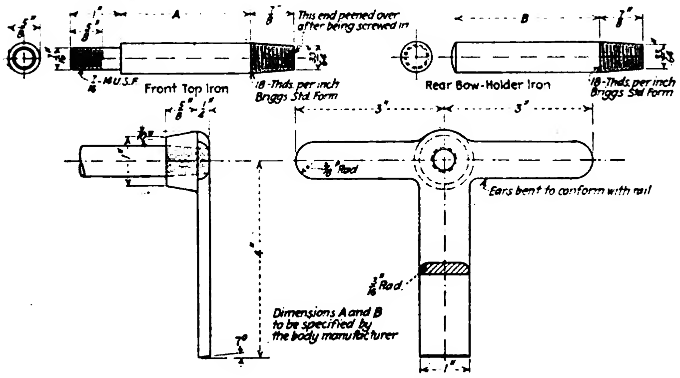


Fig. 1—Through-the-Rail Type of Front and Rear-Top-Iron

so that they and their customers will not be handicapped in the way they have been handicapped in the past when an automobile was put out with a battery compartment of such dimensions as to preclude the use, for either original equipment or renewal, of any but one special make and type of battery.

Another point is the need of a name to distinguish the single-compartment container from the present case and jar. It is stated that the word "container" is not desirable on account of its similarity to the word "retainer" and because it has been used in a general sense already. The words "case," "box," "tray" and "jar" are already used as names of battery parts.

Tank Caps

The following comments in the matter of specifying the minimum size of the filler opening of automobile gasoline-tanks have been referred to the members of the Parts and Fittings Division. The present S.A.E. Recommended Practice for Tank and Radiator Caps, page C58, S.A.E. Handbook, does not specify the minimum size of opening, only the diameter of the threaded portion for both internally and externally threaded filler-openings having been determined upon.

The demand today is for a gasoline pump that will deliver a given amount of gasoline in the shortest possible time. Pumps have therefore been designed for use in service stations with 1¼-in. hose and nozzles.

Complaints are received by pump manufacturers that the nozzles on these pumps are too large to fit into the openings provided in the gasoline tanks on many auto-

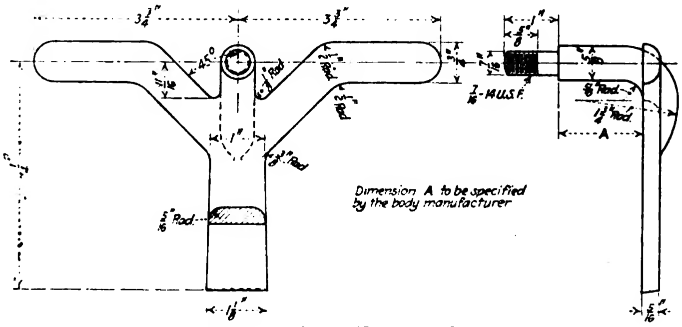


Fig. 2—Through-the-Rail Type of Front Top-Iron

mobiles. This means that pump manufacturers are obliged to put on a small nozzle, thus restricting the discharge and defeating in a measure the advantages gained from a large pump. If an effort is made to force the delivery with the smaller nozzles, it requires more strength and the gasoline is delivered at a high velocity.

Some automobiles are provided with large openings; 2½ in. is common. This matter should be taken up with the automobile builders as it is to their advantage to provide openings of proper size so that gasoline tanks can be filled quickly.

Sometimes the trouble is due to the connection to the tank being made by a pipe with an offset in it of small diameter. The smallest straight opening that should be used is 2 in. and where the connection is made to the side of the tank by a short pipe with an offset in it, it should be larger with the curve at a greater angle.

Top-Irons

O. H. Clark, who was appointed a Subdivision of one to formulate a recommendation on top irons in February, 1921, recently submitted a tentative report, in connection with which attention is called to Figs. 1, 2 and 3.

This report is based on a survey of present-day top-iron practice, which showed a great variety of types and sizes. A careful analysis of the data, however, indicated that the great majority of top irons are made with 7/16-in.-14 United States Form Threads. This thread has therefore been specified and should meet with general approval. The top-iron types recommended cover all general requirements. The through-the-rail type of front top-iron can be used through the rail by body builders who do not wish to provide for the removal of the top iron in case the permanent or California type of top is used. This type of top iron is superior to the separate through-the-rail type of front and rear top-irons inasmuch as it is not necessary to counterbore such large holes through the rail for the top-iron sockets, avoiding the weakening of the top rail.

This report was discussed at the last Passenger-Car Body Division meeting, but no definite action was taken. It was felt that probably only the threaded shank on the top-iron can be standardized, as there are so many varying condi-

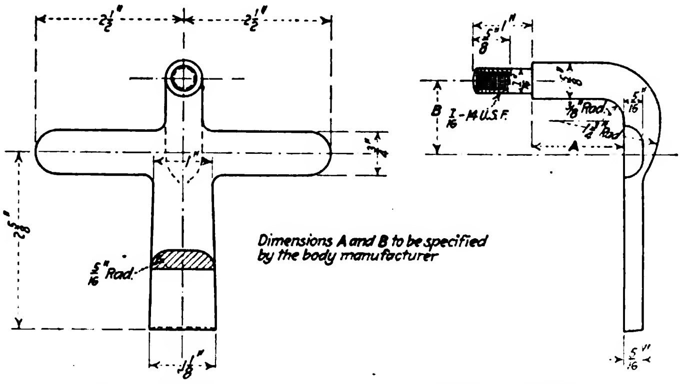


Fig. 3—Over-the-Rail Type of Front Top-Iron

tions that control the other dimensions and shapes, and as no one top-iron can be used interchangeably on different bodies or cars.

Windshield Side-Arms

It was suggested at the last meeting of the Passenger-Car Body Division that a standard should be formulated for the shanks on windshield side-arms, so that body builders can provide standard holes in the body frames. It was thought that the shank diameters should be in odd-number sizes and the holes in even-number sizes, and that there should be a definite series of lengths and threaded ends.

The Society is to circularize the windshield manufacturers for suggestions and data in this connection before further action is taken.

Inch-Type Thrust Ball-Bearings

At the last Ball and Roller Bearings Division meeting criticisms and suggestions in connection with the present thrust-bearing standards that had been submitted to the Society were discussed. It was the consensus of opinion that the present standard should remain as published in the S.A.E. Handbook, it being stated by several members that they are in satisfactory form and use.

Metric-Type Thrust Ball-Bearings

At the Oct. 11 meeting of the Ball and Roller Bearings Division the history of the development of the present metric-type thrust ball-bearing standards, which include only the general types and the ranges of tolerances, was reviewed. The entry of the United States into the recent war necessarily postponed consideration of these standards in co-operation with foreign manufacturers, particularly those in Germany.

A Subdivision, representative of practically all thrust ball-bearing manufacturers, was appointed to consider and report on this subject.

ACTIVITIES OF THE SECTIONS

Schedule of Sections Meetings

JANUARY

6—Washington Section—Aviation Meeting

13—New England Section—Visit to Stanley Plant in Newton, Mass.

17—Buffalo Section — Pneumatic Truck Tire Temperatures — Professor Ellenwood Commercial Aviation—L. B. Lent

26—Pennsylvania Section — Follow-up of Annual Meeting Papers

FEBRUARY

3—Washington Section

3—Mid-West Section — The Constitution of Matter—Prof. H. B. Lemon

8—Minneapolis Section — Road-Building Machinery and Engineering

10—New England Section — Isolated Lighting Plant Meeting at Boston or Worcester. Paper by Mr. Wilkins of the H. C. Dodge Co.

21—Buffalo Section—Resilient Wheels — A. C. Vauclain

23—Pennsylvania Section — Current Business Conditions and the Engineer's Place in the Commercial Development

The Sections meetings held in December were for the most part devoted to the general subject of commercial aviation. Various phases of this topic were considered at the different meetings by a number of well-qualified speakers.

The interest in these meetings, as indicated by the splendid attendance, proved conclusively that it is necessary from time to time to conduct a widespread campaign both through meetings and with the help of the newspapers of the Country for the purpose of disseminating the current facts regarding aerial navigation.

If the public has been led to believe that the mishaps and accidents of aeronautics are the only side of the picture, it is because too few facts have been given out showing the progress which has been made in safety, regularity of service, and cost.

An account of the various meetings is given in more detail on another page.

A schedule of the meetings of the various Sections for the months of January and February and a list of the Secretaries of the different Sections with their addresses are printed elsewhere on this page.

Secretaries of the Sections

Buffalo Section—George Pettit, 1569 Jefferson Street, Buffalo

Cleveland Section—E. W. Weaver, 5103 Euclid Avenue, Cleveland

Dayton Section—R. B. May, Dayton Engineering Laboratories Co., Dayton, Ohio

Detroit Section—B. Brede, assistant secretary, 1361 Book Building, Detroit

Indiana Section—B. F. Kelly, Weidely Motors Co., Indianapolis

Metropolitan Section—F. E. McKone, 347 Madison Avenue, New York City

Mid-West Section—T. Milton, 140 South Dearborn Street, Chicago

Minneapolis Section—C. T. Stevens, Reinhard Brothers Co., Minneapolis

New England Section—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston

Pennsylvania Section — T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia

Washington Section—B. R. Newcomb, 211 Victor Building, City of Washington

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

TESTS OF CENTRIFUGALLY CAST STEEL. By George K. Burgess. Bureau of Standards. Technologic Paper No. 192. Published by Superintendent of Documents, Washington. 22 pages.

Six castings manufactured by the Millspaugh centrifugal process were examined as to their physical and chemical properties, including hardness, tensile strength, impact resistance, density, internal stress, segregation, soundness and microstructure, both in the condition as cast and after various heat-treatments. This investigation shows the possibilities of substituting heat-treatment for forging in this type of casting.

NICKEL. Bureau of Standards Circular No. 100. Published by Superintendent of Documents, Washington. 106 pages.

This is one of a series of Bureau of Standards bulletins on metals and alloys in each of which all of the best information resulting from tests and investigations of the metal considered will be grouped. The several physical and chemical properties of nickel are given and the methods of its manufacture and working are outlined. The more common nickel alloys are reviewed and an appendix includes a condensed bibliography on this metal.

SHORT PAPERS FROM THE COOPERATIVE OIL-SHALE LABORATORY. By M. J. Gavin and L. H. Sharp. State of Colorado Cooperative Oil-Shale Investigation Bulletin No. 1, Boulder, Col. 68 pages.

This paper is a presentation of the results of preliminary studies at the Colorado Cooperative Oil-Shale Laboratory by the Bureau of Mines and the State of Colorado. The investigations are for the purpose of determining by large-scale laboratory retorting tests, those conditions that will produce the optimum yield of the best quality of products from Colorado shales. The fuel and total heat values of oil-shale and its products are studied and compared with those of other fuels. The analytical distillation of shale oils from Colorado and Scotland is given with similar data on Pennsylvania crude oil. Data on the weights and composition of shale are included.

ZINC-CYANIDE PLATING SOLUTIONS. By Wm. Blum, F. J. Liscomb and C. M. Carson. Bureau of Standards Technologic Paper No. 195. 19 pp.

During the war zinc plating, or electro-galvanizing, was applied extensively for the protection of steel against corrosion. For this purpose zinc-sulphate or zinc-cyanide solutions can be employed, but the latter produce more uniform distribution of the metal upon irregularly-shaped parts. This paper describes the results of experiments upon the preparation, analysis and operation of zinc-cyanide plating solutions. It was found that in the preparation of such solutions a considerable economy could be effected by the use of zinc oxide to replace part or all of the zinc cyanide commonly used for this purpose. Complete formulas and operating directions are given for the use of these plating solutions. It is believed that the information may be of considerable value in facilitating the use of zinc protective coatings, either alone or as a foundation for nickel or other finishes where both appearance and permanent resistance to corrosion are important.

ECONOMICS OF PETROLEUM. By Dr. J. E. Pogue. Published by John Wiley & Sons, New York City. 375 pages; numerous tables and charts.

In presenting the Economics of Petroleum, Dr. Pogue has rendered an important service to the many industries in the development of which petroleum or its products play an important part. We find collected in this volume a mass of data and a careful analytical discussion of the topic, which should be in the hands of all who are concerned with the economic phase of the petroleum problem. The author has used excellent judgment in the selection of material and, after prefacing each chapter with a concise statement of the general aspect, has presented this material in carefully devised charts and tables that are pleasing to see and easily understood. The discussion is presented in a terse and readable style and is confined closely to the topic in hand. There is of course considerable necessary repetition involved in the introductory paragraphs to each chapter. The treatise is creditable for its unbiased presentation of facts and logical deductions, as well as for the absence of bias on controversial topics.

The chapter on the motor-fuel problem is of particular interest to the automotive industry, as are other chapters devoted to specific industries, in particular that on the relation of the coal industry to the oil industry. The international features of the situation are covered with some care.

THE AGRIMOTOR, PRESENT FAILINGS AND FUTURE PROSPECTS. By H. Scott Hall and H. G. Burford. Paper read before the Institution of Automobile Engineers, 28 Victoria Street, Westminster, S.W., London, England. 17 pages.

The authors endeavor to give their ideas of the development of a true agrimotor. The discussion traverses the lines of natural argument and development that have been passed over in America, including the influx of automobile ideas resulting in the conclusion that the agrimotor finally will not be an automobile but a special new machine requiring a thorough knowledge of, and design in accordance with, a different set of facts and data. A review is given of the evident advantages of the tractor over the horse with regard to fatigue and time of accomplishment, and doubt expressed as to whether the plow as now made is the ultimate solution of soil operation or whether the separate plow and tractor are ideal. The authors believe that the tractor is not necessarily the correct idea as compared with the possible outfit, the agrimotor that covers all operations, and consider whether the machine should be a combined hauling and field operating machine.

Questions of weight, speed, hitching and line of draft are sketched from the British point of view, in which it seems a task to eliminate the extra man on the plow and make the outfit a one-man unit as has been the case in America for years. The difficulties of meeting the wide range of row-crop spacings lead through an intricate suggestion of telescoping axles and means for rapid change of overall widths, and this develops again the query, Are we spacing our crops right?

The authors believe the ultimate agrimotor will be distinctly a field machine. The complexities of the differential gear are treated, the conclusion being reached that this element should be eliminated or designed to be locked in straightaway operation. The paper is well worth reading.—O. B. Z.

HIGHWAYS GREEN BOOK. Second annual edition. Published by the American Automobile Association, Riggs Building, City of Washington. 480 pages.

This is an informative volume in three parts dealing with road improvements under Federal, State and local control; the construction and maintenance of rural roads; and miscellaneous data and tables, the topics being treated by the leading road experts of the Country.

Part 1 gives a résumé of highway legislation, the Federal Aid Road Act and progress thereunder and matter descrip-

tive of highway management and financing in the various States, together with an analysis of the Townsend bill and an intensive presentation of the arguments for good roads. The drainage of roads and the future reinforced concrete highway for 30-ton traffic are subjects of special interest in Part 2, among others. A résumé of highway engineering educational courses is included in Part 3, and among other interesting features are reports of traction tests showing the economy of improved roads; motor-car, truck and motor-cycle registrations and gross receipts therefrom for 1920; and the registrations of cars and trucks for 9 years. A bibliography of roads and allied subjects is presented and tables stating the weights and measures of road materials are given.

Design and Manufacture of Pneumatic Tires for Motor Vehicles. By Colin Macbeth. Paper read before the Institution of Automobile Engineers, 28 Victoria Street, Westminster, S.W., London., England. 102 pages.

The author discusses pneumatic-tire functions broadly, in order of importance, as being inclusive of provisions for (*a*) comfort, in allowing high speeds on poor surfaces such as can be obtained only when using wheels having a yielding periphery; (*b*) safety, in providing a sure grip on all conditions of road surface when driving, but particularly when accelerating, braking and cornering; (*c*) reliability, in protecting the air container from penetration by road obstacles; (*d*) durability, in insuring long mileage and failure only because of wear and tear; (*e*) accessibility, in making it reasonably easy to fit and to remove tires whenever necessary; and (*f*) efficiency, in the securing of the absorption of the minimum amount of engine power.

The features limiting the scope of the designer and the details that allow him scope are commented upon under four and five divisions respectively, the characteristics of the rubber mixings used being mentioned under degrees of hardness and vulcanization, their disposition and their volumetric and area costs. The quality and disposition of metal parts, molding and vulcanizing systems and types of rim are discussed at some length and illustrated, prefatory to a description of how a pneumatic tire of the well-known type is designed and manufactured, its specification being given first.

Design is detailed under considerations of tire beads, rim tolerances and rim types, bead cores, casing dimensions, rolling factors, tread and casing resistance to obstacles and the effect of inflation on the tire surface in contact with the road.

Tire manufacture is described under headings that include the preparation of the canvas and the rubber and subdivisions comprehensive of the entire process, copious illustrations being supplied throughout the paper and a lengthy discussion of it being appended.

Motor Truck Transportation. By F. Van Zandt Lane. Published by the D. Van Nostrand Co., New York City. 153 pages; 50 illustrations.

The author has written an interesting treatise on the simpler economic phases of motor-truck transportation that should be of value particularly to readers who are interested in establishing cost-accounting systems for truck operation. It is recognized by the author that the numerous factors in the cost of operation depend so much on local conditions that an attempt to give even illustrative figures is likely to be misleading; hence he confines himself wisely to a rather careful analysis of what these factors are and how they may be taken into consideration in accounting systems. He gives for comparison also a similar analysis, without figures, for costs of horse-drawn traffic and railroad traffic.

The critical reader gains the impression that, while the author has carefully enumerated all the apparent factors of cost, his failure to evaluate these factors has led to a somewhat exaggerated endorsement of the almost universal superiority of the motor truck for a very wide range of conditions, in spite of numerous warnings that he has included against this attitude. The later chapters of the volume afford an interesting review of developments in bodies, loading devices, maintenance methods and trailers, and a discussion of solid and pneumatic tires, the special problems of the farmer, and the economic possibilities of good highways.

Crippling Strength of Axially Loaded Rods. By Fr. Natalis. Translated from Technische Berichte. National Advisory Committee for Aeronautics Technical Note No. 31. Published by the National Advisory Committee for Aeronautics, Washington. 34 pages.

The formulas hitherto employed for the calculation of rods subject to compression, are usually of value only for stout or slender rods. A new empirical formula has been developed in this article, which holds good for any length and any material of the rod, and agrees well with the results of extensive strength tests. Tables giving the crippling load for solid and hollow sectioned wooden rods and steel tubes of different thickness and length are included. A graphical method of calculation of the breaking load is derived in which a single curve is employed for determining the allowable fiber stress.

Test of a Standard Liberty-Engine Cylinder Mounted on a Universal Engine Crankcase. Air Service Information Circular, Vol. II, No. 199. Published by Chief of Air Service, Washington. 10 pages.

This test was conducted to obtain the power, friction losses, temperatures and heat transfer characteristics of the standard Liberty-engine cylinder when mounted on the McCook Field universal test engine crankcase. It was concluded that the brake-horsepower output of a multi-cylinder engine can be safely estimated to be, at the normal range of operation, the product of such output of a single cylinder on the universal engine and the number of cylinders. Neither the fuel consumption nor the indicated horsepower output is so comparable, however.

Interesting tables of test data are included which show that at 1500 r.p.m. the maximum brake mean effective pressure was 122 lb. per sq. in.; the mechanical efficiency, 80 per cent; and the fuel consumption, 0.64 lb. per b.hp-hr. Careful analysis was made of the mechanical losses as determined in the test.

Applicants *for* Membership

The applications for membership received between Dec. 1 and 20, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

AHLERS, MILTON THEODORE, assistant engineer, City Machine & Tool Works, *Dayton, Ohio.*

ALAND, RICHARD C. J., engineer, Thermatic Oil Refiner Co., *Detroit.*

BASSETT, CYRUS W., sales engineer, Bethlehem Steel Co., *Bethlehem, Pa.*

BRIAN, ERNEST, coach superintendent, Detroit-Cadillac Motor Car Co., *New York City.*

BROAD, ROBERT ELTON RODMAN, student, Armour Institute of Technology, *Chicago.*

BROWN, GARNET C., sales engineer, L. H. Gilmer Co., *Tacony, Philadelphia.*

BURSIK, FRANK JAMES, student, Armour Institute of Technology, *Chicago.*

CANAVAN, J. JEROME, transportation engineer, 619 Chapman Building, *Los Angeles, Cal.*

CORBIN, ERNEST L., student, Purdue University, *Lafayette, Ind.*

CROSSMAN, S. B., assistant service engineer, Detroit-Cadillac Motor Car Co., *New York City.*

DOMJAN, RALPH, tool designer, service department Detroit-Cadillac Motor Car Co., *New York City.*

EBERHART, CLEBURNE, JR., president, Eberhart Steel Products Co., Inc., *Buffalo.*

ELLISON, LUKE V., automotive service, Ellison Service, *South Deerfield, Mass.*

ENGBRECHT, HERMAN J., service manager, National Motor Sales Co., *Chicago.*

FEZANDIE, EUGENE, student, Columbia University, *New York City.*

FISCHER, KARL W., automobile repair foreman, Detroit-Cadillac Motor Car Co., *New York City.*

FOLTZ, HAROLD H., president and general manager, Foltz Truck Service Co., *Akron, Ohio.*

FOSTER, J. P., superintendent, Maui Agricultural Co., *Paia, Maui, T. H.*

GERMAN, JOHN WESLEY, assistant treasurer, Detroit-Cadillac Motor Car Co., *New York City.*

GREENHOE, CLAUDE, engineer, Hyatt Roller Bearing Co., *Detroit.*

HAINES, W. S., experimental engineer, Mercer Motors Co., *Trenton, N. J.*

HAMMERL, JACOB, body engineer, Packard Motor Car Co., *Detroit.*

HAWKINS, PAUL I., department foreman, C. L. Best Gas Traction Co., *San Leandro, Cal.*

HO, YAO, draftsman, Baldwin Locomotive Works, *Philadelphia.*

HUGGINS, E. MELVILLE, chief engineer, Snead & Co., *Jersey City, N. J.*

JOHANNESSON, R., sales director, Textileather Co., 1819 Broadway, *New York City.*

JONES, LESTER G., student, Columbia University, *New York City.*

JONSSON, JOHN ERIK, student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

KEARNS, CHARLES M., general manager, Kearns-Dughie Motors Corporation, *Danville, Pa.*

KIMBELL, ARTHUR W., secretary and general manager, Cinch Fastener Corporation, *Chicago.*

KOELBLE, EDNA O'CONNOR, 370 Manhattan Avenue, *New York City.*

KOHL, J. J., assistant manager, City Machine & Tool Works, *Dayton, Ohio.*

KOPSHAC, J. C., general mechanical superintendent, Detroit-Cadillac Motor Car Co., *New York City.*

KUKELKORN, GEORGE A., final inspector, Detroit-Cadillac Motor Car Co., *New York City.*

LARSON, V. L., chief draftsman, E. F. Norelius, 430 Andrus Building, *Minneapolis.*

LEHMAN, HAROLD E., engineering department, Stutz Motor Car Co. of America, Inc., *Indianapolis.*

LEIGHTON, WILLIAM E., auto inspector, Detroit-Cadillac Motor Car Co., *New York City.*

LENT, LEON B., engineer, Aerial Transport Corporation, *New York City.*

LILLIBRIDGE, H. W., engineer, Atwater Kent Mfg. Co., *Philadelphia.*

LORENZ, HARRY H., technical shop consultant, Detroit-Cadillac Motor Car Co., *New York City.*

MARQUIS, ALBERT C., salesman, Rauh's Tire & Auto Supply Co., *Dayton, Ohio.*

MARSHALL, WILLIAM J., 765 Lincoln Place, *Brooklyn, N. Y.*

MESSINGER, CARL W., Detroit sales representative, Stanley Works, *New Britain, Conn.*

NISSAR, A. R., deputy head, Central Technical Institute, *Byculla, Bombay, India.*

NOFSINGER, CHARLES W., student, University of Illinois, *Urbana, Ill.*

OHSAWA, GEN, student, University of Illinois, *Urbana, Ill.*

PARSONS, CHARLES EDWARD, chief engineer, Deppe Motors Corporation, *New York City.*

PHELAN, HERBERT C., tool-salesman, Cornwell-Quality-Tools Co., *Cuyahoga Falls, Ohio.*

PLASTERER, KENNETH C., foreman of machine shop inspection, Midwest Engine Co., *Indianapolis.*

REIHMER, LEO LESTER, student, Armour Institute of Technology, *Chicago.*

REUTER, IRVING J., general manager, Remy Electric Division, General Motors Corporation, *Anderson, Ind.*

RICE, HERBERT H., president and general manager, Cadillac Motor Car Co., *Detroit.*

RIEGER, EARL CHARLES, student, Armour Institute of Technology, *Chicago.*

RUSSELL, ALBERT J., distributor for Dorris Motor Car Co., *Los Angeles, Cal.*

RYDER, C. D., chief engineer, Corcoran Victor Co., *Cincinnati.*

SHOEMAKER, HARRY, salesman, Girard Automobile Co., *Philadelphia.*

TICHBORNE, WALTER F. C., resident manager, Detroit-Cadillac Motor Car Co., *New York City.*

TROAKE, SAMUEL S., chief inspector, Detroit-Cadillac Motor Car Co., *New York City.*

WALTER, GEORGE MARTIN, manager parts service department, Detroit-Cadillac Motor Car Co., *New York City.*

WINQUIST, GEORGE WALTER, student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

WOOD, HENRY M., secretary, Trailmobile Co., *Cincinnati.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Nov. 10 and Dec. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

Allan, Robert K. (F M) chief draftsman, Skefko Ball Bearing Co., Ltd., *Luton, Bedfordshire, England.*

Anderson, Ralph W. (E S) student, Buffalo Technical High School, *Buffalo,* (mail) Apartment 14, The Matthewson, 294 South Elmwood Avenue.

Beegle, Clifford H. (J) salesman, Union Drawn Steel Co., 237 Joseph Campau Street, Detroit.

Blakeslee, Herbert G. (A) sales engineer, Splitdorf Electrical Co., Newark, N. J., (mail) 1022 Geary Street, *San Francisco.*

Chenoweth, Opie (J) field man, Peoples Loan & Trust Co., *Winchester, Ind.,* (mail) 335 East Washington Street.

Clark, Ralph R. (J) partner, Willard Service Station, 301 Seventh Street, *San Pedro, Cal.*

Curtis, Paul R. (A) 210 Arlington Street, *Wollaston, Mass.*

Deschamps, Rene (M) works manager, Minerva Motors, Ltd., *Antwerp, Belgium,* (mail) 176, Rue Van Schoonbeke.

Dwyer, Robert E. (M) director of motor-bus traffic, Commissioners of Lincoln Park, *Chicago,* (mail) 601 Diversey Parkway.

Edwards, William H. (J) research department, American Telephone & Telegraph Co., New York City, (mail) 45 South Portland Avenue, *Brooklyn, N. Y.*

Girdler, Louis T. (A) secretary and treasurer, Standard Automotive Parts Co., *Muskegon, Mich.*

Grandstaff, Ben F. (A) manager, repair parts department, Munger Automobile Co., *Dallas, Tex.,* (mail) 121 Foster Street.

Gustafson, Hugo H. (M) chief draftsman, Master Truck Co., *Chicago,* (mail) 11252 Stewart Avenue.

Hamm, Harry L. (A) automotive instructor, Air Service Mechanics School, Chanute Field, *Rantoul, Ill.,* (mail) P. O. Box 537.

Hardy, Leo J. (M) automobile body engineer, Osgood Bradley Car Co., *Worcester, Mass.,* (mail) 311 West Boylston Street.

Harrison, Jack (A) superintendent of service, Packard Motor Car Co. of Boston, 185 Aborn Street, *Providence, R. I.*

Kahn, Frank (J) aeronautical draftsman, Naval Aircraft Factory, *Philadelphia,* (mail) 2732 Montgomery Avenue.

Krause, Emil F. W. (A) expert and sales organizer, Utility Battery Co., *Chicago,* (mail) 2334 North Sawyer Avenue.

Kulicke, F. W. (A) sales engineer, Atwater Kent Mfg. Co., *Philadelphia,* (mail) 5216 North Fifteenth Street.

Lee, George H. (A) 735 Fourth Street, Northeast, *City of Washington.*

Lennox, Frank H. (A) assistant manager and sales manager, Hoover Steel Ball Co., *Ann Arbor, Mich.,* (mail) P. O. Box 387.

Meyer, F. H. (A) American Automotive Parts Co., 707 Canal Road, *Cleveland.*

Neelans, Harold G. (E S) R.F.D., *Hazardville, Conn.*

Obuchowski, Anthony (J) mechanical draftsman, Jaxon Steel Products Co., Chapin and Horton Streets, *Jackson, Mich.*

Pulford, H. L. (A) Sterling Motors, Ltd., *Winnipeg, Man., Canada,* (mail) 58 Middlegate Avenue.

Reiter, R. H. (A) manager, Perfection Piston Ring Co., *Ravenna, Ohio.*

Schaufele, William H., Jr. (J) layout draftsman, O. Armleder Co., Cincinnati, (mail) Fairfield and Washington Streets, *Bellevue, Ky.*

Schelling, Robert F. (J) mechanical engineer, Pierce-Arrow Motor Car Co., Buffalo, (mail) 107 Richmond Avenue.

Senior, Thomas K. (M) assistant chief engineer, Cleveland Automobile Co., *Cleveland.*

Sheehan, Daniel J. (E S) mechanical engineering department, Purdue University, *Lafayette, Ind.,* (mail) 11 South Fourth Street.

Smith, George Walter (J) 6094 Linwood Avenue, *Detroit.*

Sparks, Harry G. (A) sales engineer, Sparks-Withington Co., *Jackson, Mich.*

Tillinghast, Capt. T. E. (S M) engineering division, Air Service, McCook Field, *Dayton, Ohio.*

Toney, C. B., Jr. (J) layout draftsman, Wichita Motors Co., *Wichita Falls, Tex.,* (mail) P. O. Box 704.

Vane, C. A. (A) general counsel, National Automobile Dealers' Association, 320 North Grand Avenue, *St. Louis.*

Waddington, Clifford W. (A) transportation supervisor, Great Atlantic & Pacific Tea Co., Jersey City, N. J., (mail) 256 Main Street, *Milltown, N. J.*

Watanabe, Sabro (F M) Nihon Tokushuko Co., *Omori, Tokyo, Japan.*

Wing, Wilford W. (J) service engineer, service department, Frigidaire Corporation, *Dayton, Ohio.*

THE

JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE ENGINEERS

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 *W. 39th St., New York*

Issued monthly, 50 cents a number, $5 a year; foreign $6 a year; to members, 25 cents a number, $2.50 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1918.

B. B. BACHMAN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. X FEBRUARY, 1922 No. 2

INDEX

Activities of the Sections		145
Air-Cooled Engine Development — Charles L Lawrance		135
Annual Meeting		77
Applicants for Membership		148
Applicants Qualified		147
Body Seating-Dimensions — George E Goddard		117
Council Meetings		142
Crowbars and Economics		96
Deoxidation of Steel		120
Distribution of Transactions and Membership Roster		109
Engineers in Public Discussion		120
Harmony in Car Upholstery — R S Quaintance		131
How Are We To Know When Business Has Really Turned the Corner? — Arthur R Marsh		97
Industrial Conditions in Europe		116
Interchangeable Manufacture		143
Internal-Combustion Engine		96
Law of Supply and Demand		116
Obituary		146
Officers of the Society		102
Personal Notes of the Members	Adv Section	2
Personnel of 1922 Standards Committee		113
Research Information Service		111
Standards Committee Meeting		121
Sulzer Marine Diesel Engine		112
Thompson Autorifle		134
Wind Tunnel		146
Men Available	Adv Section	48
Positions Available	Adv Section	58

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. X February, 1922 No. 2

The Annual Meeting

WHAT was the 1922 Annual Meeting? It was the culmination of another year of constructive effort on the part of all automotive engineers. It was proof that the prediction made last year to the effect that automotive engineers would play their full part in the effort to restore that proper economic balance which is essential to national prosperity had come true. Further, it was a demonstration of what cooperative effort on a large scale can accomplish. From the opening of the Standards Committee Meeting on Tuesday morning, Jan. 10, to the end of the Passenger-Car Session on Friday afternoon, Jan. 13, the period of all the technical and social activities of the week, the evidence was cumulative and conclusive, as demonstrated by the quality, scope and subject matter of the papers presented, that the serious painstaking work of automotive engineers during the past 12 months had resulted in something worthwhile, something well worthwhile, something that they and others can use as a stepping-stone to further progress and therefore something that will benefit humanity.

When one considers the exigencies of modern life, its exorbitant demands upon an individual's time, his money, his physical and nervous energy, what does it mean when a single industry can send nearly 800 representative members to spend a week at some central point for the express purpose of reporting upon standardization, research and experimental work, and to outline and correlate future plans for progress? This is what the automotive industry did in this particular instance. It means that members of the Society realize the economic importance of their work, that its demands for progress are so insistent as to permit of no delay, and that they, and those who could not attend, are willing and anxious to subordinate their personal affairs to general cooperative effort that is certain to produce general and good results.

Few people realize the vast scope of the automotive industry. Let us glance over the program of this Meeting and remember that each subject scheduled is a *general* subject, representative of an infinitude of detail. The materials of construction, research, design, construction and operation; motor vehicles, motor ships and aircraft; the internal-combustion engine, its fuel and all else that pertains to any one of them are touched upon either directly or indirectly as one follows this program through. Thus, the automotive industry is alive and enters into or influences every life.

Standards Committee Reports

The Reports submitted by 16 Divisions of the Standards Committee covered 35 subjects with reference to which recommendations had been formulated since the Summer Meeting of the Society at West Baden, Ind., last May. Thirty-two of the proposals were approved substantially as submitted, there being slight revision, resulting from discussion in the Standards Committee Meeting, of the recommendation for Non-Metallic Conduit and Copper Sheet, Specification No. 71. The Generator Flange Mountings report was referred back to the Electrical Equipment Division by the Standards Committee, and the revision of the Engine Testing Forms submitted was referred back to the Engine Division at the Society meeting.

Probably the most important report passed upon is that of the Iron and Steel Division, this being a complete revision of the entire Iron and Steel Specifications. The most extensive revision of the report was embodied in Part IX, General Heat-Treatments. This part gives an outline of the general heat-treatment for representative composition of the groups of S.A.E. Steels in accordance with the best modern metallurgical practice. It also includes revised data in the form of simplified charts of physical properties, extended to include a number of types of steel for which such data have not been published heretofore in the S.A.E. HANDBOOK. The Division is preparing similar data for the types of steel not so covered in its current report.

The report of the Passenger-Car Body Division also is important, particularly as it is the first report of this Division, which was organized as a result of the intense interest shown at the 1921 Annual Meeting of the Society with regard to body standardization.

A report was submitted by the Tire and Rim Division in the form of recommended practice for a revised list of pneumatic-tire and rim sizes for passenger cars and motor trucks. This recommendation was presented as a report of progress only, however, because of unexpected circumstances arising among the tire manufacturers in connection with such a recommendation. The Tire and Rim Division expects to submit a conclusive report on the subject at the 1922 Summer Meeting of the Society.

The Reports of the Divisions to the Standards Committee were published on pages 383 to 435 of the Decem-

ber 1921 issue of THE JOURNAL. The revisions in these reports, together with the important discussion of them, are specified elsewhere in this issue. A mail vote on final adoption of the reports as revised will be opened shortly and closed on March 11. All of the members who are entitled to vote will be furnished letter-ballots in this procedure under the Regulations Governing the Standards Committee.

AIRPLANE ENGINE SESSION

The first of the technical sessions, held on Tuesday evening, was devoted to airplane engines. There were 136 members and guests present and judging from the trend of the discussion they were about evenly divided as advocates of air and water-cooled engines. V. E. Clark guided the discussion as chairman, first introducing Charles L. Lawrance who read the paper of the evening on Air-Cooled Engine Development. Mr. Lawrance acquainted the audience with the intensive study that has been made of air-cooled cylinder design in this Country and in Great Britain during and since the war. He showed the progressive changes in the proportions and location of cooling-fins, styles of cylinder-head and provision for exhaust-valve cooling, and outlined those advantages of aluminum that practically demand its use for sections in which rapid heat-dissipation is essential. He stated that air-cooled engines developing approximately 25 hp. per cylinder, which are being produced commercially, have the same performance ability as the best water-cooled engines.

H. M. Crane opened the discussion with a summation of the weak points in connection with air-cooled engines that led him to favor water-cooled types. He expressed the view that the water-cooled type has proved to be more rugged, even when considered as a unit with the radiator and piping. He criticized the radial air-cooled engine as being difficult to overhaul and mount; and stated that the fins break too easily, that the visibility of the pilot in a forward direction is reduced unduly with this type of engine, and that he had found the task of conducting the exhaust gases away from the pilot difficult. D. R. Harper mentioned a Bureau of Standards test that indicates that 16 per cent of the head-resistance due to the engine is caused by engine parts and valve-gear that play no part in the actual cooling. He agreed with Mr. Crane that the centering of the cooling function in the radiator makes it possible to combine minimum head-resistance with maximum cooling-efficiency. G. J. Mead, in his prepared discussion, compared the reliability, performance, durability and cost of air and water-cooled aircraft engines. He advanced the opinion that the two types are equally reliable; that the advantage in performance of either type has not been established in flight tests; that the water-cooled engine is the more durable; and that there should be little difference in first cost. Further, that the air-cooled aircraft engine still has to prove its power, durability and controllability in extensive service-tests. Capt. G. E. A. Hallett, of the Air Service Engineering Division, felt that the greatest percentage of forced landings has resulted from failure somewhere in the water system of water-cooled engines. For this reason alone, he recommended that air-cooled airplane-engine development be encouraged. He mentioned the attainment of 130 lb. per sq. in. brake mean effective pressure in an experimental air-cooled cylinder at McCook Field, with very low fuel-consumption. This compares favorably with water-cooled engine performance. In these tests the exhaust-valves cooled very satisfactorily, Captain Hallett stating that in this respect the engine was superior to the Liberty engine. H. S. McDewell contributed discussion on the matter of comparative steps in heat transfer as between water and air-cooled cylinders. He also called attention to the fact that nose-type radiators are being superseded by radiators of increased efficiency and lessened head-resistance that are mounted elsewhere in the slipstream. This development naturally enhanced the water-cooled engine's all-around desirability. Mr. McDewell presented last-minute data on the performance of an air-cooled engine of Mr. Lawrance's design that was tested by the Navy, this engine producing a brake mean effective pressure of 123.3 lb. per sq. in. S. D. Heron, a former associate of Dr. A. H. Gibson, of England, answered many of the questions raised in the discussion and his remarks were received with unusual interest in view of his intimate relation to most of the British air-cooled engine research during the war. C. B. Dicksee submitted some cylinder-temperature data and emphasized the importance of Mr. Lawrance's paper to the automobile engineer who is seeking a means of accomplishing the proper combustion of heavy-end fuels.

In closing the discussion, Mr. Lawrance disagreed with Mr. Crane regarding the matter of the air-cooled engine's ruggedness and called attention to the simplicity of its crankshaft and bearings. He said that the same care must be exercised in handling water-cooled engines as in the case of air-cooled engines; and that more serious damage would result from water-pump or jacket breakage than from broken cooling-fins. The simplicity of procedure in the mounting and dismounting of the air-cooled radial aircraft-engine was cited by Mr. Lawrance as a strong point in its favor, and he was of the opinion that the major working parts of the engine are more accessible than those of the V-type water-cooled engine.

BUSINESS SESSION

The new plan of conducting the business session met with much favor, the reports of the Vice-presidents of the Society, in addition to the address of the President, holding a great deal of interest and value to the members. The intention to portray the respective automotive activities of the Society during 1921 was well carried out.

RESEARCH

H. M. Crane, vice-president for aviation, and chairman of the Research Committee, discussed briefly the work of the Research Department, Dr. H. C. Dickinson being forced to be absent owing to illness in his family. Mr. Crane said that one of the most important things regarding research work is the collection and dissemination of information. Whether consciously or unconsciously, in the past many have come to the meetings of the Society hoping to meet other engineers and talk over this, that or the other problem with them. That, undoubtedly, is the most pleasant and profitable thing to do, but it is not always possible, and for many of the younger members it is practically impossible. The Research Department, if it meets expectations, will help to fill this gap and act as a great clearing-house of information for all the Society members, including the juniors and everyone who is interested in research work.

The second idea is that this collection and dissemination of information will initiate a great educational movement throughout the ranks of the Society and also in many institutions such as universities and laboratories where research work is undertaken. A great quantity of research work fails to produce worthwhile results on account of wrong methods of attack or the use of insuffi-

ciently accurate apparatus. Sometimes an entire misapprehension of the problem that is being attacked is followed by a number of very interesting readings that have no bearing on the subject.

Undoubtedly in the long run the university laboratories will be very useful adjuncts to the already over-worked laboratories of the industry in connection with the many problems of research that are confronting us.

Mr. Crane asked for the earnest cooperation of all the members of the Society in answering the Research Department questionnaires, furnishing all the information that they reasonably can, with due consideration for the rights of their own companies. He said that if they do this they will get in return from the Research Department information of value in greater amount than they furnish it to the Department.

PROGRESS IN AVIATION

Mr. Crane expressed the conviction that aviation made a great stride forward in 1921 in spite of the relatively small amount of money available for development work. The steady efforts exerted in many countries to make the airplane commercially useful have added greatly to our fund of knowledge and have been laying a foundation on which eventually will be built a most important addition to our means of transportation.

The attempt to use wartime machines in commercial service resulted in many failures so far as economic effectiveness is concerned, but from each failure came some additional data. The men of the industry and, to some extent, the public are becoming acquainted with what service can reasonably be expected. During this year a still greater advance in the direction of realizing just what real transportation service is should be made. A lack of this realization in the past has been the cause of our failure to make the most of the wonderful speed of the airplane.

In many cases those attempting to establish airplane lines have not seemed to appreciate that in the case of passengers the points of departure and of destination are almost invariably the home and the office, and in the case of mails or merchandise the post-office and the warehouse. The time in transit will be figured invariably in this way and no amount of speed during portions of the trip will have any permanent effect on the public point of view. The greatest handicap that must be overcome before we can expect to see commercial aviation successful on any considerable scale is the almost entire absence of terminal facilities adapted to commercial service. As it is usually stated, we have no suitable landing-fields. For commercial purposes the location of landing-fields is of essential importance. The Pennsylvania Railroad spent many millions of dollars to bring its passengers across the Hudson River and into the heart of New York City, and yet before the building of the Hudson River tunnels the Pennsylvania station and its various Metropolitan terminals were far better located for commercial transportation than the most accessible landing-field near any big city. The fact that an airplane can fly 100 m.p.h. means nothing at all if the terminal facilities do not allow a satisfactory use of that speed. Until we encourage the people of the Country to provide terminal facilities that are useful for commercial transportation, we will not have any commercial transportation. Each one of us can, by using his influence and talking to others, including political representatives, assist in fostering a point of view that will bring a big improvement in this line. The commercial airplane-terminal will have to be for a long time to come a community interest of some kind and, presumably, financed and controlled by the Government.

It is natural that the present situation exists. Most of the flying fields were started as experimental flying fields and were located at considerable distances from centers of population. We have not begun to make an impression on what should be done where the greatest amount of commercial transportation is going to be required in the long run; that is, between cities like New York, Chicago, St. Louis, Boston and Philadelphia. It is only under the most favorable circumstances in length of haul and poor railroad service that the airplane can be expected to overcome the present inefficiency in terminal service. It is clearly the duty of the Society to preach the gospel of air transportation and to point out the only road that can lead to ultimate success.

This short review would not be complete without a reference to the bombing tests carried out jointly by the Army and the Navy last summer. These tests showed a degree of efficiency in the percentage of hits and in the destruction caused by the larger bombs that created a very considerable sensation among the people as a whole. I do not agree with those that see as a result of these tests an immediate revolution in methods and apparatus of warfare on land and sea, but there is no question that the aviation arm will hold in the future an even more important place in the scheme of national defense.

The past year has seen many new records made in aviation, of speed, altitude and endurance, but I think that the most important records have been made in the Air Mail Service and in the transportation lines, both here and abroad. Records of the sporting type have their uses in stimulating the imagination and in arousing general public interest. They also furnish considerable engineering information of value, but the thing that we need now is the knowledge of how to conduct a regular daily service at a minimum cost and fairly certain data as to what that cost will be.

There has been a considerable advance during the past year in the construction of both powerplants and planes. It has been proved that the powerplant and plane must be the result of painstaking development and gradual evolution. They cannot be produced by a sudden leap into the dark on the part of the designer. This is particularly the case in respect to the complete airplane in which the installation of the powerplant and accessories has the greatest possible bearing on the safety of the operation. I have never been able to see how a really good installation could be expected on the first model of a new design, when the designer's attention is naturally focused on the strength of the airplane fabric and its flying characteristics. It is only on the second or third model of a given series that the installation gets the attention that it deserves. The same thing applies to the engine designer, who now has time to realize that the engine must be mounted in an airplane to be of real service, and that a successful brake-test is not the final answer.

TRACTOR ENGINEERING

Concerning the tractor engineering developments of 1921, Vice-President E. A. Johnston reported that, while much of the previous development activity was curtailed, due to retrenchment, considerable valuable work had been done through concentration on essential problems. There is an evident desire on the part of both the builder and the owner of tractor outfits to favor a dependable, as well as more durable, outfit, making these two factors take precedence over a minutely economical unit as re-

gards fuel. This is particularly noticeable in the choice of second purchases, repeat orders being almost uniformly in favor of the higher-grade equipment.

High-class construction now includes working parts of high-grade material, parts fully enclosed from dust and dirt, well lubricated bearings, liberal use of high-grade anti-friction bearings or, in the case of plain bearings, liberal proportions of good quality. Heat-treatment of steels has been extended to all parts adaptable to this process and its refinements.

Reducing the weight of tractors by the use of high-grade materials and designs has necessitated more and more attention being given to wheels and lugs. Therefore much work has been done during the past year to establish the relative values of various types of lugs, widths and diameters of wheels, and the relations of speed to draft, although there is still a great amount of research work to be done along these lines. The generally accepted operating and plowing speed is now approximately 3 m.p.h.

While many two-plow outfits have been produced, and their sale has excelled, there is a tendency toward a larger or three-plow tractor that will accomplish 50 to 60 per cent more work at the same labor cost. Further, there is a marked tendency toward operating the wheels of a wheel tractor in the furrow, which limits the width of drive-wheels to 12 in. for a 14-in. bottom. This, together with the tendency toward reduced weight, results in more difficult problems of developing lug equipment, lubrication, and meeting the various conditions due to slippage and steering.

Elements and equipment such as ignition apparatus, carburetion and distribution, lubricants and methods of lubrication and air-cleaning have improved noticeably. These features are relatively more necessary to the purchaser than refined economy. The convenience and safety of the operator have been studied better, resulting in greater comfort and less strain during operation.

A distinct interest has developed and brought forth much improvement in power equipment, to be used with and without the tractor, thus extending the usefulness of power-driven apparatus.

Standardization work has received much attention, especially along the lines of bolts, nuts, valves, splines, bearings, ratings, material, belt speeds and pulleys.

Some interesting development in light-weight tractors of the track-layer type has appeared. Also, considerable progress has been made in the development of steam powerplants for tractor purposes.

The ever-present question of liquid fuel, its cost, supply and suitability, has caused a marked demand for alcohol developments. This call comes largely from foreign fields, where sugar refuse is available, as in the Philippines, Hawaii, Cuba, Brazil, Argentine, Esthonia and France.

The agricultural farm power equipment industry is firmly established and with the continued improvements and refinements, resulting in greater dependability, durability and economy, it is reasonable to assume that the demand for this class of equipment will increase rapidly.

THE MOTORBOAT FIELD

Vice-President Joseph VanBlerck said that when the Society inaugurated the development of standardization in the motorboat field, enthusiasm was high and interest very keen. Many promising projects were undertaken and some of them were well started when the war interfered and it became almost impossible to get members together on this work. After the war, by the time the work could be taken in hand again the present depression in business had set in, and since the engine and motorboat industries received their setbacks along with others, the matter has been practically at a standstill.

The most pressing need is to secure the cooperation of additional members in the work of the Motorboat Division of the Standards Committee. The standards that have been formulated by the Society, applying to motor vehicles, have been almost universally adopted. This alone proves the value and need of standardization work. In fact, the use of the S.A.E. Standards in the motor-vehicle field is becoming so much a matter of course that there is danger of the credit for the establishment of them by the Society being overlooked by manufacturers in general.

STATIONARY INTERNAL-COMBUSTION ENGINEERS

Theodore C. Menges, second vice-president for stationary internal-combustion engineering, submitted an excellent analysis of the business and engineering conditions in this field. He said that the great volume of the business comes from the demand of the farmer and that there is a gradual slacking up of the industrial tension and that sales are beginning to pick up.

The stationary-engine business has been built up by various companies specializing on certain types of engines. Very few have tried to cover the entire field. The business naturally groups itself under the following divisions:

(1) Large engines
(2) Electric-Light Engines
(3) Pumping Engines
(4) Concrete-Mixer Engines
(5) Milking-Machine Engines
(6) Railroad-Section Handcar Engines
(7) Contractors' Engines
(8) Air-Compressor Engines
(9) Well-Drilling Engines
(10) Farm Engines

By large engines are meant engines of 15 hp. and over. They are used principally for operating (*a*) powerplants, (*b*) custom elevators, (*c*) custom feed mills, (*d*) waterworks, (*e*) electric lights, (*f*) grain threshers and (*g*) ensilage cutters. For purposes *a*, *b*, *c*, *d* and *e* the engines are usually of the single-cylinder horizontal type. Some of the larger plants are equipped with vertical multiple-cylinder engines. For purposes *f* and *g* single-cylinder horizontal portable engines are used mostly. The tractor is gradually crowding out this type of engine for grain threshing and ensilage cutting.

There are two types of electric-light engine; the large stationary engine for small cities and the small self-contained unit for individual use. The large engines usually have extra-heavy flywheels and run at a higher speed than ordinary stationary engines run. They are generally throttle-governed, and run on kerosene. The small self-contained electric-light unit is a vertical engine direct-connected to a dynamo. The entire apparatus, including the switchboard, is mounted on an iron subbase. The tendency is to furnish a radiator and a fan for cooling the water. Some of the very successful plants are air-cooled. Nearly all of them operate on the four-cycle principle.

For small pumping jobs most of the engines used are of the ordinary single-cylinder horizontal type. The pump is operated by a belt-driven jack that is clamped

directly to the pump. Another type of engine is geared to the pump. In this the jack is built into the engine. For heavy deep well-pumping, the type used is called a geared-base engine. It has a set of larger gears and bearings built into it. This type is used at waterworks and railroad-pumping stations.

Both the vertical and the horizontal types of engine are used for concrete mixing. Working in the dust and dirt, it is necessary to have them well housed. This line of business is about the most active of any at the present time. This is, no doubt, due to the price of concrete compared with wood construction and to the greater use of concrete for building purposes.

Milking-machines have provided a new field for stationary engines. The engine usually is equipped with a reduction-gear to give the slow speed required by the machine. The engine is used to operate the vacuum pump that forms the principal part of the machine. This field is growing very rapidly. The milking-machine is proving to be of great assistance to the dairy farmer.

The smaller type of engine is used on the common handcar. The pump levers are taken off, a pulley is put on the axle and a belt from the engine drives the handcar. In some of the larger and more elaborate jobs the installation consists of a multiple-cylinder engine with a transmission. The use of an engine saves a great amount of time and has proved to be of great value, not only to the section-man but to the railroad itself.

Stationary engines are used by contractors to fill ditches and to operate cut-off saws, planers, and similar machinery; also for hoisting purposes, in which case a geared-base hoist is built into the unit.

For garage use air-compressor engines are usually small and of the horizontal type, driving the compressor with a belt. For larger jobs the engine is direct-connected to the compressor and both are mounted on a substantial iron subbase.

Well-drilling engines are usually of the horizontal type and mounted on the same truck as the well drill. They have an attachment on the governor, so that the engine speed can be varied. A large number of these units are self-propelling. A recent oil-well drilling outfit included a large four-cylinder vertical engine. This job was 50 ft. long between the wheels and 25 ft. high. It weighed 10 tons.

Engines used on the farm are of various sizes and for different purposes. The small horizontal engine is used mostly for pumping. It runs also the washing-machine, the cream-separator, the churn and the milking-machine. The larger engines are used for sawing wood, grinding feed or cutting ensilage. The demand is for an engine that is complete, with all parts mounted on skids, so that it can be moved around.

Ignition

Electric ignition of the battery and the magneto types is used. The source of electricity for the battery ignition has settled down to the dry battery. The most common form of battery ignition is the make-and-break. Due to the fact that the batteries do not last long and are not reliable enough, this form of ignition is gradually being displaced by magneto ignition.

Three methods of low-tension magneto ignition are in use: (*a*) high-speed rotary, (*b*) direct-geared rotary and (*c*) oscillating. The high-speed rotary magnetos have been driven from the rim of the flywheel, delivering a direct current passing through a coil. This form is rapidly disappearing due to its mechanical shortcomings. Direct-geared rotary magnetos are used on almost all makes of stationary engine. They are simple in construction and, running at engine speed, are very durable and reliable. Oscillating magnetos are of the high-tension and the low-tension types. The high-tension oscillating magneto has not been used to a very great extent in this Country, but is used largely in foreign countries. The low-tension oscillating magneto is being used on some makes of engine. It is installed in connection with a make-and-break igniter and forms a part thereof. The mechanical action of the heavy springs that jerk the armature of the magneto at the time of producing the spark is a serious drawback to their use. They are good for starting an engine, but are subject to severe strain when the engine gets up to speed.

Governors

Centrifugal governors are used on stationary engines. They are operated generally at crankshaft speed but are sometimes geared to run at higher speeds. They operate on two different principles. Governors that control the butterfly or throttle-valve located in the intake-manifold control the speed of the engine. The engine takes an explosion every time, but the strength of this explosion is controlled by having a heavier or lighter charge of the mixture taken in to the cylinder. This form is usually called throttle-governed. The hit-and-miss governed engines, which are in a large majority at present, control the number of explosions or charges that are taken into the cylinder. This is accomplished by causing a catch to stop the valve motion, and to hold the exhaust-valve open. A heavy load will cause the engine to take a large number of explosions. A light load will cause it to take a small number of explosions. In this form of governing the quality of the charge and the compression-ratio always remain the same. Consequently, these engines are very economical. The exhaust-valve, being held open, allows the engine to draw in and expel several charges of cold air. This keeps the engine cool and helps to scavenge the cylinder. Hopper-cooled engines use less water when of the hit-and-miss type than when throttle-governed, because they have a chance to cool down between explosions. It is for this reason that this type is seldom run on kerosene. Kerosene is generally used in throttle-governed engines because they stay hotter.

Cooling Systems

Air-cooling is used on some of the smaller engines. It is used extensively in cold climates where there is danger from freezing the cooling water. It has not proved practical for the larger heavy-duty engines. Water-cooling is accomplished in several different ways. Tank cooling consists of having a large stationary tank filled with water and allowing the water to become cooled by evaporation and by contact with the air. Overflow water running through the cylinder jacket and discharged after being used is the method most employed on very large engines. This is wasteful of water, but gives the best results, as the temperature of the cylinder can be accurately maintained at the most efficient point. Radiators, installed with a fan, are suitable for complete unit powerplants. They take up a very small space and do not require much water. They are employed on a large number of small electric-light plants. They are fitted also to portable engines. Water-pots or hoppers are in use on almost all small stationary engines. The water-pot is simply an enlargement of the top half of the water-jacket. It holds enough water to keep the engine cool

for ordinary work. It is easy to fill and drain, is durable and has proved its worth.

Lubrication

The lubrication of the engine is, of course, very important. There are four principal methods in vogue at the present time: (*a*) drop-feed, (*b*) mechanical, (*c*) splash and (*d*) grease-cup. Drop-feed oilers are used on almost all small engines. They have a pipe inside of them to equalize the pressure above and below the oil. A ball-check prevents the explosion pressure from blowing into the oil. A screw-stem pointed at its lower end regulates the flow of the oil. Mechanical oilers are common on the larger engines and on portables. They are driven by a belt, a chain or gearing. They are positive in their action and are considered valuable. Splash lubrication is found principally in vertical engines with enclosed crankcases. Some horizontal engines have this system, although it is not very reliable or much used in this type because too much oil is thrown into the cylinder. Grease-cups are fitted on almost all small engines. They lubricate the connecting-rod and main bearings. Grease seems to give better results on babbitt bearings than oil. These cups require very little attention and are very reliable. A cup usually has to be filled only once a day.

Gasoline Mixers

Gasoline mixers as used on stationary engines are operated according to three different systems: (*a*) float-feed, (*b*) pump-feed, and (*c*) suction-feed. Float-feed mixers are employed on unit electric-light plants and on some portable engines, although not very extensively. Pump-feed mixers are used on a number of engines. They are made in two styles: (*a*) force-pump and (*b*) submerged-pump. The force pump draws the gasoline from a tank located outside of the building, or out of the engine base, and forces it into a small reservoir attached to the mixer. The surplus gasoline flows back to the tank. This system is found principally on large engines and is recommended by the insurance companies. The submerged pump has its plunger submerged in the gasoline contained in the reservoir. It simply lifts the gasoline from the tank and discharges it into the reservoir that forms a part of the mixer. Suction-feed mixers are components on almost all small engines. The suction of the piston in the engine draws up the gasoline directly from the tank into the cylinder. A check-valve keeps the gasoline from flowing back and prevents back-firing in the tank.

New Designs

A few new engines have been put on the market this year. Among these may be mentioned the Cushman, the Stover, the Waterloo Boy and the International. These new-style engines are smaller and lighter than previous models, run at a higher rate of speed, and are well balanced and govern very satisfactorily. There is a tendency to use steel drop-forgings as much as possible. Die-cast removable bearings are employed almost exclusively. These are made of babbitt only and are not bronze-backed. There is a tendency toward lead-base bearings, which seem to run cooler. These engines are all hopper-cooled. Most of them have their base, frame and cylinder cast in one piece. Several of them have a removable sleeve inside the cylinder to permit replacement after wear or breakage. Accurately made interchangeable parts are used to a great extent. Smoother and better finished castings on these engines indicate an advance in foundry practice.

Where possible the S.A.E. Standards are being incorporated in their design. This is especially true in the case of piston-rings.

During the war practically all stationary engines were put out to run on kerosene, due to the high cost of gasoline. This forced the builders to use throttle-governed engines. They gave good satisfaction on fair loads, but on light loads, as when pumping water, they were not entirely satisfactory.

The hit-and-miss engine is back in the field again and seems to be the one mostly demanded.

Conclusion

Summing up the status of the stationary engine today, Mr. Menges said that the demand is for a comparatively light-weight, high-speed, hit-and-miss engine. The engine has a tank in the base and suction feed. It has a make-and-break igniter and a low-tension built-in magneto. It is hopper-cooled with water. It is entirely self-contained and is mounted on a set of substantial skids. It has smooth well-finished castings and is painted to withstand outdoor usage.

The prospects for the future trade are good and a steadily increasing demand is expected. As in all other lines, it will be a matter of the survival of the fittest. The manufacturer who meets the demand honestly and fairly will certainly reap the harvest.

THE STATUS OF THE ENGINEER

President Beecroft addressed the members on The Status of the Engineer in Automotive Economics, after paying his "very highest and sincerest respects to the excellent Council and the organization that stood back of the Council" during his administration. He spoke of this period as 12 months of wonderful cooperation, the members of the Council, the Officers, the chairmen of the committees and the office staff showing that devotion to work by much sacrifice of time and energy that alone makes a society such as the Society of Automotive Engineers possible.

He said

> I direct your attention to the future because I believe that today we must look to the future; we must accept the old adage, Let the dead past bury its dead. We must act in the living present and make our actions of today efficient by having our vision focused ahead on what we believe to be the eventual goal.
>
> I would be, in trying to add to the picture that has been made before you today, as a schoolboy in his earliest hours of school, with shaking hand, with untrained muscles, with untutored mind, attempting to create what will be his and what he will execute in the years to come. We should survey the past to see how easy has been our course. The roots of the present are always found in the past, and we must study the past if we are to proceed correctly, interpreting sanely the days that are to come.
>
> In the last 20 years our paths have been rather pleasant. I wonder whether we appreciate how fortunate we were in the days when we laid the foundations of our industry. We have seen the national wealth of our Country more than doubled since 1900. Has not our national per capita wealth had very much to do with the wondrous, spectacular and unprecedented development of the automotive industry?
>
> Let us, as we stand in the midst of the greatest problems that have confronted our industry, be sure that we have the correct perspective, and be not blinded by the successes of the past, which have come not entirely because of efforts that we have exerted but largely on account of the rapid development of industry during the first 20 years of this century.

Let us look briefly at agriculture and see the development that has been made in it. Bear in mind that 45 per cent of the population of this Country is dependent for livelihood upon agriculture. We have learned during the last year that when agriculture is depressed the cities in the agricultural areas follow its course closely. The towns of 2000 population respond almost instantly to the condition of the individual farmer. The cities of 40,000, 60,000 and 100,000 population in the agricultural areas of the great Mississippi Valley reflect the economic status of the farmer within not over 8 to 10 months.

To be specific, take a city in Iowa that had an unexpectedly good business during part of 1921, while the farmers of that State and the farmers of the corn belt were not purchasing. It stopped purchasing some 3 or 4 months ago, and the reason is not far to seek; the farmer had not paid his bills to the merchants of the city; he had not met his obligations at the banks, which were naturally shorter of fluid funds than they were a year ago. We cannot divorce the towns and cities of an agricultural area from its farmers.

The value of farm property has doubled while we have been working to build up our industry. The total value of farm machinery per farm has increased three-fold since 1900. This machinery has increased production; it is partly the cause of the movement of the boys from the farm to the centers of population.

We have had also an increasing crop-value. Corn, our greatest crop, had a value of $9 per acre at the opening of this century. Today its average value per acre has risen to $15. Perhaps we find in that one of the reasons we have had the great sale of automobiles to the farmer. If we take our spring wheat crop, we find again that its value has increased from $7.50 to over $12 per acre. The oat crop has increased from $7 to approximately $11; the potato crop from $34 to $62. Our great cotton crop has increased in value per acre from $15 to $23. In the case of the winter wheat crop we find an increase of from $8 to $13 approximately. Bear in mind that these are not war increases but the equivalents of increases up to the year 1913.

Have we not as an industry profited greatly from these increases in farm and crop values? Are we giving those agricultural conditions that we have come through due credit? If we considered the increases during the period of the war, we would see in each case a greatly ascending curve which, of course, has fallen off in the last year.

Let us, as representatives of our industry, give credit where credit is due. With the figures I have quoted in mind, we can perhaps discount better the problem that lies ahead. It is generally conceded that we will not see in the next 20 years another great increase in crop values, because other agricultural areas of the world, such as Argentina, Australia, India, Egypt and the Union of South Africa, as well as Western Canada, are coming into very close competition with us.

INTERNATIONAL AFFILIATION OF ENGINEERS

First Vice-President Horning spoke on the subject of international affiliation of engineers. He said:

Strikes are going on all the time that have nothing to do with labor; there are strikes of capital and there are strikes of men who are quietly desisting from doing the things that, in view of their peculiar mental and temperamental characteristics, they should be doing for the world. Capital is on a great strike. It is buying up tax-exempt bonds. This is one of the grievous economic and financial problems of the Country.

Laborers are going on strikes, or have gone on strikes in the past, but there is a strike that is eating insidiously at the great benefits the world should have from engineers and inventors, and that strike is the one thing that is keeping us from solving many problems. I maintain that throughout the world there are ideas in the safe boxes and in the minds of men that would solve many a problem if these men were sure of a fair deal or a just return for their effort. One of the things that have prevented many very good inventions in this Country, as well as in Europe, is that inventors invariably have felt that they were not sure of a return. Only in the dire stress of poverty have they let go of some of their ideas. Our fuel problem and many of the most serious problems that face us are suffering for solution because inventors are not sure that they will get their just return in the markets of the world.

If our patent system could be revised so that there would be fairness to inventors, if it were more certain that their efforts would be rewarded and that there would be sure jobs for them, and that they would be comfortable in their work and happy in their environment, great things would come.

I have received so much benefit in my own work from contact with foreign engineers that I cannot help but pay a great tribute to them. Before the war the isolation of Europe was almost complete to all except the chosen few. Today it seems no farther off than Boston or Cuba seemed then.

Engineers have been drawn together and the cooperation between the engineers of the struggling nations that led to magnificent accomplishments during the war has emphasized the great value that accrues to those who are willing to accept the influence of the broader aspects. There exists a fundamental difference in viewpoint that arises out of the character of the trade that must be served by the engineers of different countries and out of the difference in their academic training and national temperament. But from a closer contact of engineers throughout the world there will develop a higher and better type of engineering.

Not over-estimating the advantages of typical American engineering, which reaches its highest stage in designs suitable for quantity production, American engineers are interested intensely in the tendencies of foreign design in connection with solving the serious problem of economical operation. The foreign markets are limited compared with our own. At this time one-third of our States have each more cars than there were in Germany, France or the British Isles at the beginning of the war. This limitation of market, the distribution of national wealth, the cost of fuel, good roads, short distances and congested traffic have combined to present problems that have been solved by the foreign engineers but are just commencing to present a serious aspect to our engineers.

The great profession of engineering is thoroughly conscious of the fact that world-wide problems face the engineers of every country and that there is a wide-open door with respect to them. There is no such thing now as isolation. With Russia, Germany and Austria in economic, financial and political collapse, we find our own Country in distress. Every part of the world is so sympathetic to conditions in its other parts that nothing can happen in any activity that is not felt instantaneously throughout the world. Having nearly 40 per cent of the gold of the world in our possession, and blessed with practically unlimited national wealth, we suffer business depression and financial distress because of the disturbed and depleted condition of Europe. Engineers in general must become more and more familiar with what their brethren throughout the world are thinking, experiencing and accomplishing.

Our industrial capacity developed by the war makes world markets necessary to our prosperity and economic stability. Engineers must be not only good scientists but also thoroughly practical world-economists. Whereas isolation has been apparently of great advantage to the mechanical trades, as evidenced by the inhospitality accorded visitors at plants, discriminating

tariffs, sparse interchange of technical literature and other forms of provincial aloofness, there is now a pressing demand in every human activity for a relaxation of regulation and a breaking-down of artificial barriers to international intercourse. Contact, association, intimate concourse, and free unobstructed international exchange will tend to keep the world at peace. An International Affiliation of Engineers has a great place in this new world of ours. Kept free from political tendencies, it will rise high in service to mankind and in promoting the pursuits of peace and happiness.

There are pressing problems of standardization, such as an International Screw-Thread Standard, the solution of which we may have to leave to future generations. We have built up immense debts for our children and grandchildren to pay. We shall fail in our larger opportunities as engineers if we do not aid them by arriving at standards that will make a ship at home in any port when it comes to repairs, and permit connecting to a port water-hydrant with an interchangeable screw-coupling in distant lands. All the various mechanisms of the world should be repairable with standard bolts, screws and nuts, alike in India and in Indiana.

Science is the foundation of engineering. Science is bringing the mind of man closer and closer to the sublime truth as to the unity of all things. Some of our most practical problems hang on the intimate knowledge of the constitution of matter. Our fuel problem rests on the same laws that make it possible for radium to melt ice in an amount equal to its own weight every hour. No nation has a monopoly of minds that will solve ultimately the enigma of matter and of energy, which when known will solve the problems of science, engineering, commerce and life.

The methods of research that arise out of national mental characteristics are of great assistance, but the assimilation of the results made possible by them is always deterred by the lack of standards of procedure and measurement. Here a great matter presents itself for solution.

Engineers must be first good scientists, then good psychologists, then good economists. It has been said that a failing of engineers is that their minds have been limited by the bare necessities of their profession. This, if true, must be obviated. Engineers can meet in full measure their duties and opportunities only when their interests and contacts are world-wide.

The Society of Automotive Engineers has been fortunate in its contact with world engineering, through its thoroughly patriotic cooperation with the Government, before and during the war, its visits abroad, and its hospitality to societies of foreign lands. It has been fortunate in having presented to it technical papers by such world authorities as Sir Dugald Clerk, Harry Ricardo, Dr. Harold Dixon, and others.

The Society looks forward with hope to a broader and more sympathetic cooperation of the engineers of the world and contemplates trustfully an effective International Affiliation of Engineers. Ambassadors of the arts and sciences can go further in the direction of world peace than "diplomatic covenants openly arrived at."

TABLE 2—APPLICATIONS FOR MEMBERSHIP RECEIVED

Date	Factory Representative Campaign[1]	Other Sources	Total
1920			
April	84	61	145
May	107	65	172
June	74	38	112
July	38	37	75
August	10	93	103
September	11	90	101
October	1	86	87
November	1	88	89
December	2	56	58
	328	614	942
1921			
January	3	68	71
February	0	65	65
March	3	89	92
April	19	77	96
May	31	59	90
June	12	54	66
July	5	19	24
August	3	32	35
September	1	36	37
October	2	47	49
November	3	63	66
December	2	72	74
	84	681	765

[1]The Factory Representative Work was begun in April, 1920, and in March, 1921.

MEMBERSHIP INCREASE

W. A. Brush stated that 2 years' experience as Chairman of the Membership Committee had led him to feel that there is not much to be said about membership increase work, but considerable to be done. He continued: I wish to say, very briefly, that in 1920 we started a membership campaign about which you all know something. I refer to the factory representative plan. That worked nicely during 1920, and we thought it would continue to function during 1921; but it did not. Our membership increase fell off during 1921 because we did not

TABLE 3—INCREASE OF MEMBERSHIP

End of Year	Total Members	Percentage Increase
1909	393	...
1910	654	66.4
1911	982	50.1
1912	1.447	47.3
1913	1,713	18.4
1914	1,743	1.8
1915	1,783	2.3
1916	2,121	19.0
1917	3,284	54.8
1918	3,986	21.4
1919	4,516	13.3
1920	5,231	15.8
1921	5,317	1.6

TABLE 1—COMPARISON OF SOCIETY MEMBERSHIP BY GRADES

Grade	Dec. 31, 1919	Per Cent of Total	Dec. 31, 1920	Per Cent of Total	Dec. 31, 1921	Per Cent of Total
Service Members	13	0.3	18	0.3	65	1.2
Foreign Members	11	0.2	50	1.0	67	1.3
Members	2,360	52.3	2,706	51.7	2,723	51.2
Associates	1,350	29.9	1,495	28.6	1,509	28.4
Juniors	514	11.4	692	13.2	671	12.6
Affiliate Members	95	2.1	112	2.1	107	2.0
Affiliate Member Representatives	110	2.4	117	2.2	85	1.6
Enrolled Students	63	1.4	41	0.8	90	1.7
Total	4,516	100.0	5,231	100.0	5,317	100.0

work hard enough in membership work. Within the last 90 days we have started a new type of campaign and are already getting some results from it.

A very significant and, to my mind, pertinent fact has made itself evident during this year. We have been securing membership applications from a constantly increasing number of industrial executives, general managers, production heads, and presidents of companies. I think that that indicates a perception, and I am using that word advisedly, on the part of the executives of the work that this Society has done for the industry and for them, for the executives, not for the engineers; and they are gradually indicating that perception by coming into the Society.

That brings me to what our beloved First Vice-President said a little while ago about engineers. Perhaps at some time in the future invention, the child of the engineer's brain, will be represented and considered as property just as much as the capital dollar is considered as property. Then we will have an engineering society that will function for the benefit of the engineer at least as much as it does for the benefit of the industry at large and for the capitalist.

That, I am convinced, is what this Society has done since its inception and is doing. It has benefited the industry and the executive as much as if not more than the engineer. So, if some time in the future there may be an engineering society that has the interest of the engineer at heart, we will have no trouble with the membership as far as the engineers are concerned.

MEETINGS COMMITTEE

Chairman C. F. Scott, of the Meetings Committee, in submitting its report, said that it has been the policy of the committee to make as small a draft as possible on the general income of the Society for meetings attended by a certain proportion of the members, so that as much as may be of the Society's income shall be available for those services that all members receive. He presented the following statistics:

Society Meetings Held during 1921		5
Annual Meeting, New York City, Jan. 11-13		
Chicago Meeting, Chicago, Feb. 2		
Tractor Meeting, Columbus, Feb. 10		
Aeronautic Meeting, Dayton, May 21		
Summer Meeting, West Baden, May 24-28		
Sections Meetings Held under the Auspices of Sections Committee		46
Papers Presented at Society Meetings and Published in THE JOURNAL		59
Papers Presented at Sections Meetings and Published or Considered for Publication		42
	1921	1920
Attendance at Annual Meeting	804	1,196
Attendance at Annual Dinner	1,107	1,504
Attendance at Carnival	815	770
Attendance at Summer Meeting	698	887

Allotment to Meetings Committee in Society Budget for Direct Expenses $15,500.00 (74 per cent of Budget)

Amount Actually Expended $10,379.17 (67 per cent of Allotment)

	1921	1920
Cost per Member for Meetings, Direct Expense after Deducting Income	$1.92	$3.24
Average Membership on Which Cost per Member Is Based	5,400	4,673
Cost per Member for Allotment General Expense, Meetings Department	$4.90	$6.67
Total Expense per Member for All Activities of the Society	$43.00	——

The Society has followed for years the policy of making its Summer Meetings self-sustaining, except for general staff expenses, by a direct charge on the members. Other meetings are made partly self-sustaining by a charge for dinner tickets.

Last year for the first time a slight additional charge for guests over that for members at the Summer Meeting was made as a matter of fairness to those who pay annual dues. A similar differential was made for the attendance of guests at the Dinner and Carnival of the 1922 Annual Meeting.

The presentation of papers at the Society and the Section Meetings is recognized today as a privilege and a distinction worthy of the best thought and effort of the leading engineers residing in this Country and abroad.

THE SECTIONS

The report of the Sections Committee, submitted by H. R. Corse, its chairman, is printed in full elsewhere in this issue of THE JOURNAL. Mr. Corse said that the Sections Committee's work has consisted of taking up the problems that came to it from time to time throughout the year, due largely to the difference of conditions in the places where the Sections of the Society are located. The Committee investigated the conditions as thoroughly as possible and then made recommendations in connection with them to the Council of the Society.

ELECTION OF OFFICERS

H. W. Slauson, H. G. McComb and A. M. Wolf were appointed tellers of election of officers to serve during this administrative year and of councilors to serve during 1922 and 1923.

They reported that 774 ballots had been cast, 45 of these being void. The total count on election was as follows:

President	
B. B. Bachman	735
Scattering	2
First Vice-President	
J. V. Whitbeck	736
Second Vice-President Representing Motor-Car Engineering	
F. E. Watts	734
Scattering	1
Second Vice-President Representing Tractor Engineering	
O. W. Young	734
Second Vice-President Representing Aeronautic Engineering	
V. E. Clark	731
Second Vice-President Representing Marine Engineering	
H. E. Morton	732
Second Vice-President Representing Stationary Internal-Combustion Engineering	
C. B. Segner	734
For Members of the Council (To serve for 2 years)	
H. M. Crane	735
Lon R. Smith	732
C. F. Scott	734
Scattering	2
For Member of the Council (To serve for 1 year)	
W. R. Strickland	737
For Treasurer	
C. B. Whittelsey	737

TREASURER'S REPORT

Treasurer Whittelsey reported that the Society's finances are in unusually good condition. During the past years, up to Dec. 31, 1921, a surplus reserve of $134,251.74 has been accumulated, the greater part of

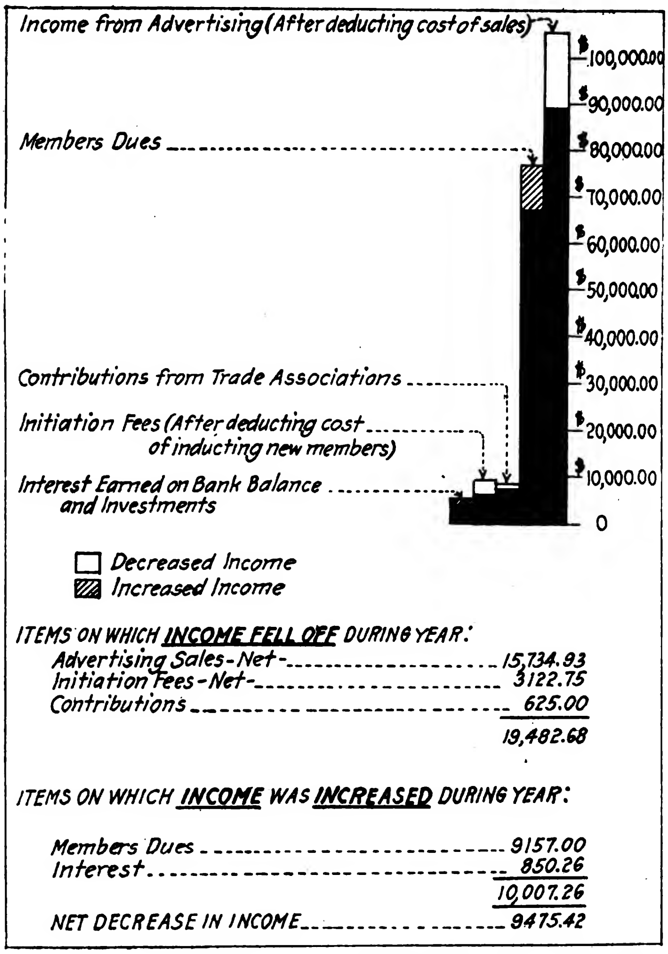


Fig. 1—Income Comparison Fiscal Years 1919–1920 and 1920–1921

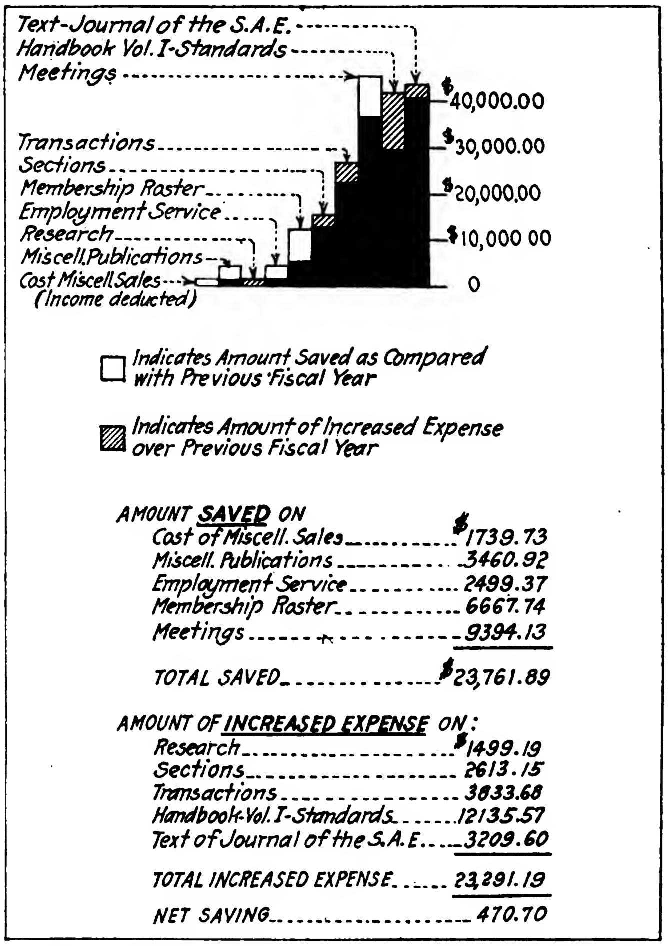


Fig. 2—Expense Comparison Fiscal Years 1919–1920 and 1920–1921

this being invested in sound securities. On Dec. 31 the Society had railroad and United States Government bonds and Treasury certificates of a par value of $100,000, the market value of which was $96,192.80. The average yield on all the securities is 4.74 per cent, which is considered excellent for absolutely safe investments.

Figs. 1 and 2 show graphically the relative values of the various items of income and expense of the Society during the 1920-1921 fiscal year as compared with the last previous fiscal year. It will be noted that the expense of the Society's principal activities was increased to the extent of $23,291.19, but that through careful management enough expense was eliminated in other departments of the organization to offset this increase. Owing to the general depression in business, the net income from advertising was considerably less than for the previous fiscal year. This loss was partly offset by an increase in the membership, with a consequent increase in members' dues. The unexpended balance of income over expense was $9,475.42, compared with $19,556.12 for the previous fiscal year. The Society's advertising revenue reached its lowest point in October. Since that time the income from this source has increased steadily.

The total income per member, after deducting cost of sales, was $34.32, compared with $41.69 for the previous year, and the per-member cost, after deducting income from meetings, was $32.57, as against $37.50 for the previous year. It will be noted that the cost of each member to the Society is more than twice as much as the dues he pays. This is made possible principally through the revenue received from advertising in The Journal, which redounds to each member and the automotive industry as a whole in the form of more and greater Society activities.

Treasurer Whittelsey was not so optimistic about the coming year and emphasized the necessity of thorough cooperation on the part of the members and the industrial leaders with the Society's affairs in keeping up the items of revenue and the prompt payment of dues. For the first three months of this fiscal year, from Oct. 1 to Dec. 31, the expenses have exceeded the income by $4,324.79.

At the organization meeting of the 1922 Council it was felt that the Society must continue its policy of constantly broadening the Standards and Research work, and to provide necessary current funds for greater activity along these lines it was thought wise to eliminate certain other expenses. The decision reached was to eliminate the greater part of the expense of printing and mailing the Society Transactions and the Membership Roster and at the same time continue to make them available to those members who wish to have them. In future the Transactions will be available to members who order them at $2 per part. Sufficient notice will be given so that members can order them before they are printed. The Roster will be reduced in size to an alphabetical list only and will be distributed to those members who request it after they have been notified that it is available.

Body Engineering Session

The Body Engineering Session repeated with increased measure the success of the first meeting of the kind held

in January, 1921. This year's attendance was very gratifying in point of numbers and included a large representation of engineers whose activities are confined exclusively to body design and production. E. G. Budd, who was chairman of the session, opened it with a short statement of the Society's work along body standardization lines during the past year and emphasized the need for most active and impartial cooperation in the future to assure the continued success of such standardization. The Passenger-Car Body Division has proved to be one of the more active Standards Committee Divisions, but Mr. Budd expressed the belief that the surface had been merely scratched in a field replete with possibilities. The paper by George E. Goddard on Body Seating-Dimensions was received with the interest anticipated and brought out the fact that body engineers are fairly well agreed on what practice it is best to follow in establishing seat-heights, seat-depths, leg-room and similar basic dimensions. J. E. Schipper emphasized the importance of providing sufficient room between the steering-wheel and the rear upper corner of the left front door-opening in order that the driver can enter and leave the car easily without disturbing his companion in the front seat. George W. Kerr called attention to the lack of room on the toeboards of most cars for the driver's left foot when the clutch is not being operated. Mr. Goddard's suggestion that a manikin be standardized for use in establishing seating dimensions met with general approval. J. Ledwinka stated that he had devised and used such a manikin with satisfactory results. Mr. Goddard urged the body engineers to forward suggestions for use in developing a standard manikin to the Passenger-Car Body Division of the Standards Committee at the Society headquarters, as the Division will undoubtedly undertake this task during the year. P. W. Steinbeck illustrated and described a new type of open-car enclosure in his paper on The California Top. In this design the windows slide back and are stored in the rear quarter of the top instead of being detached and stored in pockets when not in use.

R. S. Quaintance presented the salient points in his paper, Harmony in Car Upholstery, with the aid of color charts that emphasized the harmony between certain colors and the lack of it between others. In response to questions in the discussion Mr. Quaintance stated that he believes blue is the most popular paint color, with gray second. It was his personal feeling that brown is the most desirable color for a closed car, because it carries sufficient red to leave an impression of warmth. He said that the selection of totally neutral colors, such as gray or black, is ultra-conservative and to be discouraged when the owner's individuality receives consideration. When asked about susceptibility to fading, Mr. Quaintance stated that blues are most liable to be affected, red and green following in order. George W. Kerr expressed the opinion that insufficient care and poor taste are used too often in selecting exterior color-schemes to match the interior upholstery of bodies. He gave examples of color combinations that are not necessarily complementary or in agreement with the color scale but pleasing to the eye. George Mercer raised a point regarding the proper display of upholstery samples and called attention to the disappointments resulting from selections made from small samples. Mr. Quaintance said that it is difficult to secure an exact impression of the appearance of any fabric in the completed car from either large or small samples and suggested the trimming of a sample body as the only certain method when the quantity to be produced warrants this expense. In closing, Mr. Quaintance advanced the thought that one of the serious mistakes of merchandising is not providing for a choice in the selection of car interiors for closed-car purchasers. Several options should be offered to the people of differing personality.

The paper on the Manufacture and Application of Automobile Varnishes and Paints, by L. Valentine Pulsifer, was one of the most interesting and instructive of those presented at the Annual Meeting. In the discussion Mr. Pulsifer brought out the serious variation in coat thickness resulting from the flowing-on method of varnish application, illustrating his remarks with sample glass panels the coating-thickness of which had been measured. He described the methods used in measuring coat thickness and also the manner in which the elasticity of the several coats was determined and how it should be graduated. The use of a flat rub-out was recommended as the most satisfactory means of producing dull-finish effects. Mr. Pulsifer's experience has shown that in forced or heat drying the temperatures should not exceed 150 to 175 deg. fahr. and that less heat should be used with each succeeding coat. When drying the final flowing coat of varnish there is little to be gained by using forced drying. As a matter of fact, it results only in dimming the luster. Mr. Pulsifier believes that the spraying system is very suitable for the application of primers, rough stuff and flat color, but contended that the spraying of varnish coats has never been accomplished satisfactorily. The need for a thorough cleansing of all metal paint surfaces was stressed and in closing some of the chemical reasons for paint failure resulting from fading were stated.

Lubrication Session

The subject of lubrication, the different kinds of lubricants and their desirable and undesirable qualities bears a close and important relation to the production and satisfactory utilization of liquid fuels. The internal-combustion engine is almost as insistent in its demand for good lubricants to lessen its mechanical friction as it is in its demand for good liquid fuel.

That the necessity for good lubricants and good lubrication in engines is realized fully by automotive engineers was made plain by the extensive research work that was summarized in the able papers that were presented at the Lubrication Session and by the close attention paid to all details of their exposition. H. C. Mougey presided.

The paper on Viscosity and Friction had been printed[2] previously and was presented in outline only by the author, Winslow H. Herschel, of the Bureau of Standards, so that more time might be available for its discussion. Among the questions discussed were the connection between viscosity and friction in regard to the amount of clearance in a bearing; what constitutes the quality known as "oiliness" in a lubricant; interfacial tension between the oil and the metal; surface tension; the thickness of oil-films; mineral oils and the addition of fatty oils thereto. The statements were made that the amount of variation in lubrication effectiveness due to differences in bearing clearances is not yet fully determined; that "oiliness" is the property that causes a difference in the friction when two lubricants of the same viscosity at the temperature of the oil-film are used under identical conditions; that interfacial tension is an interaction between the oil and the metal; that surface tension has little effect; that very little experimental work has been done to determine the thickness of oil-films; and that, since there is slight difference in mineral oils as regards

[2] See The Journal, January, 1922, p. 31.

oiliness, organic substances are necessary at times to increase this effect. The need for some method of test to determine when an oil has been refined sufficiently, so that it is neither over- nor under-refined, was emphasized, and mention was made of the lubricating properties possessed by an oil of light viscosity, but having great oiliness, obtained from petroleum-base shale-oils having a large content of unsaturated hydrocarbons.

The relation between fluid friction and transmission efficiency, which was the subject of the paper presented by Neil MacCoull, of the Texas Co., is one concerning which small appreciation is evidenced in the related literature, there being a lack of necessary data regarding the variable factors of automobile friction-losses such as the quantity and viscosity of lubricants, the efficiency of worm-gearing and part-load modifications. Experiments to determine the mechanical losses, including all friction losses between the working gases in the engine and the driving wheels of the vehicle are described in this paper, and supplementary data are included from Professor Lockwood's experiments at Yale University.

Three distinct possibilities for increasing the fuel economy of a motor vehicle are specified and enlarged upon, gearset experiments to secure and develop data for a four-speed gearset being described and commented upon at length; photographs and charts illustrative of the equipment used and the resultant data are included. The effects of varying the speed under no-load and load conditions are studied, inclusive of mathematical analysis, and the efficiency of the gearset and noise measurements made in regard to it are discussed.

An interesting item of information was mentioned by Professor Lockwood, during the discussion that followed, to the effect that preparations have been made by the University of Kansas to study wind-resistance by mounting motor vehicles that are under consideration on a raft that floats on a lake that is often subject to high winds. The raft enables the vehicle to be turned to face whatever wind may blow, the expectation being that this will afford many advantages over wind-resistance studies made in wind-tunnels.

The paper by Robert E. Wilson and Daniel P. Barnard, 4th, on the Mechanism of Lubrication, presents the general theory of "greasy" and fluid friction, and partial and complete lubrication, and points out that all the customary quantitative tests and specifications for oils are designed mainly to meet conditions of fluid friction where the motion of the bearing carries and maintains a film of liquid between the metal surfaces. It was stated that the present specifications for lubricating media are illogical and inadequate and that tests should be developed that will measure the comparative value of the lubricant under conditions of partial lubrication. Such tests would be invaluable, not merely to the users of oils in choosing the one best suited to their needs, but also to the producers in affording a sound method of determining the value of various processes of refining and blending their products. Several possible methods of measuring the value of an oil under such conditions are considered, some of the essential results obtained therewith being discussed.

The importance of fundamental experimental work to determine the precise mechanism of lubrication and the composition and structure of the film that is effective in partial lubrication is emphasized. The hypothesis is offered that the latter consists of a plastic or gel-like solid rather than a liquid film that is produced by the selective absorption of certain constituents by the solid surface. These constituents are believed to be of a colloidal nature, and to constitute a comparatively small proportion of the greater number of mineral oils in common use.

An extensive research program has been undertaken at the Massachusetts Institute of Technology to study some of these fundamental aspects of the mechanism of lubrication. Certain new methods of investigating lubricating films are described in detail, with comment on the preliminary data obtained. In general, the results appear to support the hypothesis of a plastic solid film composed mainly of certain colloidal constituents in the oil.

The discussion following this paper related to the subjects of glycerized lubricating solutions, fatty acids, adsorption, the effect of the porosity of bearing surfaces such as cast iron, and kindred details. Much interest was manifested in the definition and thorough understanding of just what constitutes "oiliness" in a lubricant. The papers and discussions were replete with informative data.

Motor-Truck Transportation Session

At the technical session on Wednesday afternoon dealing with the problems of motor-truck transportation two papers were presented; one by Walter Jackson, dealing with the Past, Present and Future of the Motor Omnibus, and the other by M. C. Horine on the Economics of Motor Transport. In presenting his paper Mr. Jackson dealt almost entirely with the present uses of the motor omnibus in jitney service for cross-country work as a substitute for interurban electric railway lines or as supplementary service to existing street railways. He brought out the fact that the rate of fare will exert a marked influence on the ability of the motor omnibus to compete with the electric railway and stated that 10 cents is the proper charge for a high-grade motor-bus service when the average length of ride exceeds 3 or 4 miles and that the only opportunity afforded for a 5-cent bus-fare is where the length of ride does not exceed 2 miles and the buses are operated by one man. Another point made by Mr. Jackson is that, while many estimates for motor-bus operation show a cost of 1 cent per seat-mile, inclusion of all the legitimate items increases this figure at least 50 per cent and possibly doubles it.

In opening the discussion C. M. Manly spoke of the effect of transportation facilities upon suburban real-estate development and said that the possibility of motor-bus facilities being curtailed to some extent exerts a retarding influence upon the purchase of land in communities that are dependent upon buses only, while this is not true to so great an extent in the case of communities served by electric railways. At the same time he stated that he realized that the mobility of the bus and its consequent ability to change the routing if conditions make this desirable at any time help to secure the interest of capital in motor-bus companies. Herbert Chase questioned the cost figures given in the paper, asking if upkeep and capital expense were included and stating that he did not see why the cost per seat-mile in a bus should be twice that of the street railway. Also, he did not concur in Mr. Jackson's opinion that the street railways are best for the cities. In response Mr. Jackson said that the seat-mile cost was based on operating costs only in both instances.

T. H. Marburg mentioned the possibility of utilizing the trackless trolley-car as a transportation medium instead of the motor-bus or the conventional electric railway car. A. J. Scaife stated that the trackless trolley has the same disadvantage of fixed routing that a regular street railway has. He said that the ability to reroute buses in case of traffic blocks or changes in transporta-

tion conditions is a great advantage for the bus. He also mentioned the congestion of traffic caused by regulations in a few of the larger cities requiring vehicles to come to a halt when the street railway cars stop to discharge or receive passengers. G. A. Green agreed with Mr. Scaife that the trackless trolley lacks the flexibility of the motor-bus and also pointed out that the wiring must be installed before the route can be operated. The cost of the overhead structure of a trackless trolley system is, he stated, from $6,000 to $10,000 per mile; in other words, it costs practically as much to install a mile of trackless-trolley system as to purchase a single vehicle.

C. T. Myers said that the upkeep costs of motor-bus systems are, so far as he had been able to learn, high. He attributed this to the high repair-costs, which he argued were due to insufficient lubrication. He stated that, based on a charge of 50 cents per hr., the lubrication of the motor vehicles in operation in the United States at the present time costs $500,000,000 per year, assuming that 2 hr. per week is required for each vehicle. This he claimed is excessive as, if the chassis were designed for proper lubrication facilities, only ½ hr. every two months is all that each vehicle would require. Mr. Green, in reply to Mr. Myers, stated that proper lubrication is a relatively simple matter and that in reality there is not much difference between the motor-bus and the trackless trolley on this point. He said that the practice of the Fifth Avenue Coach Co. is to lubricate each bus after each 2000 miles of running and that, due to the employment of hollow shafts and members whereever possible, only 15 min. is required.

H. W. Slauson emphasized the necessity for protecting the motor-bus not only by legislation but from restrictive legislation. The conflict between the enactments of the 48 State legislatures and the numerous municipal and county ordinances is a serious problem. L. C. Porter called attention to the lack of illumination in the buses and said that the companies should do everything possible to forestall legislation along this line. He pointed out that, while lighting is provided for the comfort of the passengers, it also possesses advertising value. He felt that the dome lights that are used in the majority of buses are inefficient and recommended that lights with suitable reflectors be employed, even if this makes it necessary to increase the headroom.

E. C. Pohlmann spoke of the conditions surrounding motor-bus development in Chicago where five different municipal bodies have endeavored to regulate operation. The pioneer motor-bus company, he stated, operated for 3 years and then went into the hands of a receiver who continued for the same length of time and then sold out on the basis of 25 cents on the dollar. A number of viaducts were located along the line of one motor-bus route in the southern portion of Chicago and these necessitated the design of an entirely new vehicle. Mr. Green said that the necessity for keeping the center of gravity low to prevent overturning, for clearing overhead structures and for good appearance demanded that the headroom of the bus be kept as low as possible. In reply to Mr. Porter's criticism of the illumination in buses he stated that work on new generating apparatus is under way and he felt certain that better illumination for buses would be available within a year.

Mr. Chase asked if anything other than size inherent in a motor-bus makes the seat cost higher than in the street car and added that one explanation might be the upkeep. He also inquired whether a special type of chassis is necessary for a motor-bus or if it is possible to utilize the truck type of chassis as produced by several companies. R. E. Fielder in answer to this last question stated that the minimum width for bus bodies is 7 ft. and that the load is concentrated around the edge of the body, especially when the bus is equipped with longitudinal seats and to a certain extent when the small transverse seat is employed. The desirable width of chassis for motor-bus work is at least 14 in. greater than that of the standard truck chassis. Another point that operates against the use of truck chassis is that the floor of the vehicle should be as low as possible. The truck chassis is from 36 to 40 in. above the ground and inasmuch as from 10 to 12 in. is as high a step as a passenger can make comfortably, it is necessary to have three or four steps, which takes up all the platform space, or use a special chassis. Mr. Marburg stated that the cost of the electric railway is divided into the four general groups of maintenance, wages, power, and interest and depreciation, some of these being proportional to the mileage operated. In the case of the bus the investment per seat-mile is much less than with the street railway and the operating expenses are proportional to the seat mileage. The upkeep of the street railway car is much less than that of the bus and the cost of the electric current used to supply power is less than that of gasoline. Mr. Green, in continuing the discussion, said that for units of the same size the bus should not cost more to operate than the street railway car, but that the possibilities for overloading the latter reduce the cost of its operation to a very material extent.

F. W. Perry, representing the Department of Plant and Structures of the City of New York, spoke of the public emergency that made it necessary for the city to operate motor-buses, street railway lines and trackless trolley-cars. In his opinion no competition is involved between these three forms of transportation. He pointed out that the load per passenger-mile is heavier in the case of the trolley car than of the bus. N. G. Shidle stated that one factor that perhaps has retarded the development of the motor-bus in this Country is the necessity for the manufacturers being sure of an output for their product before beginning work. In England the motor-buses are operated by the tramway companies, and that is true, he thought, to a large extent in this Country. Both forms of transportation have particular fields in which they are most efficient, and for the so-called middle zone special studies must be made to determine which is the more efficient and economical. A special type of chassis is necessary for motor-buses. The competition of buses with cars from the standpoint of riding comfort and lighting was touched upon by Mr. Scaife, who said that the average jitney is rough-riding, uncomfortable and poorly lighted, due to the placing of practically any form of body on a truck chassis. He agreed with other speakers that a special type of chassis for motor-bus work would be developed.

J. E. Hale cited several factors that enter into the question of whether motor-buses should be used for transportation in any given situation. These were the cost to the rider, the maintenance of schedules, speed, safety of operation and the reluctance to permit the operation of street-railway lines in residential districts. Aside from the question of cost, the most important point is whether the bus can transport passengers more quickly than street railway cars. In this connection he brought out the fact that where jitneys compete with established street-railway lines they are preferred to the cars on account of the speed at which they transport the passengers. He said that in a number of cities railway companies also furnish electric light and power and that if the

motor-bus displaces the electric car as a mean of transportation there is a question as to what effect this would have upon the electric-light and power service of the communities involved.

Practically every speaker who participated in the discussion of the paper on Economics of Motor Transport, by M. C. Horine, emphasized the necessity for taking steps to prevent the enactment of legislation restricting the operation of motor trucks. In presenting his paper Mr. Horine pointed out that the amount of traffic is not responsible for the deterioration of the road and that the impact of the moving vehicles is not as serious as was formerly considered. While legislation limiting the size of truck used to 7½-ton would affect only 1 truck in approximately 25,000, he felt that steps should be taken to prevent such restriction. Another point upon which he placed emphasis was that the motor trucks contribute more than their share of the expense of building roads in the form of license fees and various forms of taxation. In response to a question by Mr. Pohlmann as to the saving resulting from the operation of a truck over a good road as compared with a bad one, Mr. Horine said that while data on this feature had differed widely in the past definite figures would be available soon.

W. P. Kennedy stated that the type of spring suspension and the tire equipment, with reference to the work to be performed, are fundamentally wrong in the motor truck as at present constructed and suggested the use of progressive spring equipment to take care of any inequalities in the road and dual solid and pneumatic-tire equipment to function at heavy and light loads respectively as remedies for these conditions. He also pointed out the waste that occurs on account of the need for producing a great number of parts to take care of the wide range of truck sizes and recommended three capacities of truck, nominally rated at ½, 2 and 5 tons respectively, as a solution of the parts problem, as well as offering a remedy for construction and to aid in the regulation of taxation. In his opinion education of motor truck users is not possible. In concluding his remarks Mr. Kennedy made a rather radical suggestion in regard to the method of constructing roads. He pointed out that not only is there a waste in road-building inasmuch as it is a seasonal procedure, but that the methods also are crude. He advocated the building of a road in the same manner as an office building as a means of reducing the cost of construction. In his opinion it is perfectly feasible to build the road sections on a mass basis at all seasons of the year and transfer them to the place of application after the subgrade has been prepared. In reply to this suggestion Mr. Perry said that it is not possible to build roads and buildings entirely in the shops and gave it as his opinion that 90 per cent of the road is in the foundation and its drainage. While it is perfectly feasible to build the wearing surface, which could be renewed, in the shop, this surface must be in sections of such size as to be readily handled by one man. If the foundations were properly built and drained, there would be no trouble about the roads wearing out. He also spoke of his observations of the French roads that have steep shoulders to carry off the water so that it does not get into the bed and cause damage. In conclusion he stated that as a general proposition the foundations are too weak for the loads carried by the roads. Mr. Pohlmann, in reply to the suggestion that certain standardized sizes of truck be built, said that the engineer must work out units that meet public opinion and fulfill the requirements of traffic. J. F. Winchester stated that while large trucks have damaged the roads, this has been due to the overloading of trucks as a result of sales propaganda. He advocated a wheel-load limit of 800 lb. per inch of tire width as being reasonable from the viewpoint of the operator of motor vehicles and also as a load that will not damage the roads. He felt that, although pneumatic tires are efficient from a road point of view, they would not compete with either the solid or the cushion tire.

H. M. Rugg emphasized the need of a trained personnel to operate the motor trucks and said that while 400,000 men are required to maintain the motor trucks in operation at the present time, only 225,000 are available and that of this number not over 40 per cent are trained or capable of performing the work that is assigned to them. He urged that engineers set a standard of training and education for motor-truck operators and repair-men and pointed out that it is only by the continual application of their knowledge of motor-truck construction that these two classes of men become experts. F. W. Davis said that the industry is faced with the fact that legislation is in process of forming that will react on the development of the motor truck. He felt that roads must be protected and classified as regards the load than can be carried, with certain seasonal variations now in force in some States. He mentioned the Connecticut motor-vehicle law which the truck builders had opposed when it was first enacted, but now considered a means of salvation that the industry had sought. The passage of similar laws throughout the United States would aid the motor-truck builder in his efforts to produce a vehicle capable of carrying the desired load and yet meet the whims of the user regarding the load to be carried, by setting a standard for the motor-truck builder to conform to. While large trucks are in the minority, a safe limit must be placed on trucks to be operated in fairness to the public who furnish the money for road construction. In this connection Mr. Davis stated that the load per inch of tire width or the load to be carried by a single axle is a workable basis. In conclusion he pointed out that, while motor trucks are essential on the highway, the industry should endeavor to secure legislation that will not be unduly restrictive and at the same time avoid the carrying of excessive loads. Such a course, he felt certain, would result in the securing of a greater mileage of improved roads without serious opposition on the part of the taxpaying public.

In closing the discussion Mr. Horine pointed out that the banishing of heavy vehicles from the roads by legislative enactment was a violation of American justice and not supported by scientific facts. While he thoroughly endorsed the scheme of classifying roads according to the load to be carried, he felt that this should be on the basis of traffic requirements rather than the present condition of the road. The economy of the motor truck is not measured by its capacity but there is a need for vehicles capable of carrying heavy loads. In connection with the remarks of the various speakers on restrictive legislation he stated that any legislation to be enacted should restrict the possibilities of the truck to damage the roads rather than its load capacity. He also stated that Mr. Kennedy's suggestion regarding three standard ratings for trucks is practically what is available at the present time.

Research Session

In opening the important Research Session toward which the many members of the Society privileged to attend had been looking forward with much interest, Chairman H. M. Crane prefaced his introduction of the eminent British automotive engineer, Harry R. Ricardo,

who read his comprehensive paper on Recent Research Work on the Internal-Combustion Engine, by saying that since the success of the Society has been due to cooperation, and since the presence of Mr. Ricardo was proof that cooperation in the automotive industry was international in character, the word "cooperation" might well become the Society's motto and slogan.

The large auditorium of the Engineering Societies' Building was used for this session, which was devoted entirely to the presentation and discussion of Mr. Ricardo's paper, and much enthusiasm was manifested by the large audience present.

The paper describes the research work on the internal-combustion engine done recently in Mr. Ricardo's laboratory in England, and presents his deductions therefrom, based upon an analysis of the evidence he has obtained to date. Fuels are discussed at length under three specific headings, many tabular data being included and commented upon, and the calculation of thermal efficiency is described. Mean volatility and detonation are discussed and the author's present views regarding turbulence are stated, this being followed by a brief summary of the conclusions reached by Mr. Tizard, a colleague of the author, following recent investigations.

The influence of the nature of the fuel upon detonation is presented, a lengthy discussion of the subject of stratification being given under three specific divisions, inclusive of comment upon the benefits derived from using weak fuel-mixtures. The paper itself is concluded with a discussion of turbulence with reference to combustion-chamber design, many charts and photographs having been included throughout.

The paper is supplemented by nine appendices, which include discussions of mechanical efficiency, under three specific headings; piston experiments, inclusive of four specified deductions; air measurement, with a description of equipment and methods; the total internal energy of the working fluid over a wide range of temperature; the influence of the compression-ratio upon the power output and efficiency; the influence of cylinder size on the performance; the influence of cylinder temperature on the power output; the distribution of heat in a high-speed internal-combustion engine; and the efficiency of a single-cylinder engine under reduced loads. This supplementary information is copiously illustrated.

Following the hearty applause that was accorded the author when he had concluded his presentation, this being given while the entire audience was standing in token of their appreciation and thanks, Chairman Crane remarked upon how difficult it is to comprehend the immense amount of creative thought and arduous labor that are involved in so exhaustive a treatise as this.

The exposition of so vast a subject as is presented by a full consideration of all factors relating to the internal-combustion engine is naturally provocative of wide differences of opinion in regard to some of its many phases, and the discussion became unusually snappy at times when some of these differences in belief were expressed. But, as was pointed out by Prof. O. C. Berry, this is exactly the desideratum of engineering convocations and he therefore advocated that automotive engineers descend from any possible pedestal of false modesty or false dignity, express their ideas fully and clearly in open forum whenever they have opportunity, and thus obtain the great benefit that follows a full and free interchange of thought.

Interest appeared paramount regarding present ideas concerning flame propagation, detonation and turbulence but other interesting factors also were much in evidence. The pros and cons of the introduction of exhaust gas into the cylinder were expressed briefly and a description of tests made with bombs to determine the ignition point of any fuel, made by the Bureau of Mines, was given. The arrival at some standard method of computing engine data, so that the necessity for any recomputation can be eliminated when different experimental data are to be compared, was advocated and it was suggested that the Society make an effort to accomplish this.

The effect on detonation of carbon on the piston and the cylinder walls was related and the experience of the Fifth Avenue Coach Co., New York City, with the Ricardo slipper-type piston was described and illustrated by lantern slides.

Questions were asked relative to the effect of spark-advance on detonation, what means can be used to determine when detonation does and does not occur, what the viewpoint of English engineers is in regard to dissociation and other pertinent topics; but, since the replies were made by Mr. Ricardo as a conclusion of the discussion and since the full text will be published in an early issue of THE JOURNAL, no attempt is made here to more than indicate the trend of thought during this session.

[As Mr. Ricardo desires to make some corrections in his paper, as preprinted, it will be impossible to publish this paper in THE JOURNAL for February as was intended. Members who desire to secure a copy of the uncorrected preprint of the paper, of which a limited stock is on hand, can do so by communicating with the Society's office in New York City.]

AUTOMOTIVE MATERIALS SESSION

At the Automotive Materials Session held on Thursday afternoon the discussion related principally to the metallurgical phases of the papers presented. With reference to the paper by C. N. Dawe on Chrome-Molybdenum-Steel Applications from the Consumer's Viewpoint, R. H. Sherry pointed out that the chrome-nickel physical-property figures given were low and suggested that a chrome-nickel steel containing 0.35 per cent of carbon be used to make a comparison. In reply to this suggestion Mr. Dawe said that it is perfectly feasible to use a 0.35-per cent carbon-steel or a steel of the S.A.E. 3200 Series and get a merit index that would differ in form from the curves shown in the paper but still bear a general relation to them. Mr. Sherry said that he did not believe in the merit index as a means of determining the use of a steel for automotive purposes and in this contention he was supported by J. H. Nelson, who said that in his opinion the merit index is a far from satisfactory guide. He also suggested the addition of Brinell hardness numbers to the tables presented in the paper as affording a means for making a comparison, and stated that from a production standpoint machinability must be secured even though the hardness of the steel be reduced in the attempt. He took exception to the statement of Mr. Dawe that the reduction of area of a steel and the impact test results bear a definite relation to each other. J. D. Cutter agreed with Mr. Nelson regarding the merit index and said that it could not be used to compare tests made under different conditions, although the curves in the paper possessed some merit as affording a means of comparison. In response to a question by George L. Norris as to how steel produced with calcium molybdenate compares with that in which ferromolybdenum is used, Mr. Cutter said that equally good results are obtainable with either but that, so far as he knew, no steel in which calcium molybdenate was used had been produced in the

last year and a half. In concluding the discussion Mr. Sherry endorsed Mr. Nelson's suggestion regarding the addition of the Brinell hardness-numbers and stated that this is necessary to meet commercial specifications in which the hardness numbers appear.

In discussing the next paper by G. R. Norton on Continuous Die Rolling, Mr. Nelson said that this process is interesting and can be made useful in connection with drop-forging. While the use of this process would save time in the forge-shop, it would restrict raw material, particularly on small jobs.

The paper by J. H. Nelson on Drop-Forging Practice aroused the most discussion of any paper at the session. Mr. Sherry asked if the use of a lead pot of say 24-in. diameter and from 6 to 7 ft. long would not do away with the variation in the Brinell hardness mentioned by Mr. Nelson. Mr. Nelson said that in his opinion the physical properties are a function of the temperature and not of the means by which this temperature is obtained. The furnaces used in making the tests reported in the paper were checked carefully with six pyrometers before being used on production work and a variation of only 5 deg. or less was permitted between the pyrometers. Mr. Sherry reported that in his experience the variation in hardness with the lead pot is small as compared with a furnace in which six and even eight thermocouples are used to control the temperature and that the lead pot possesses the additional advantages of a lower cost and the securing of a more uniform product. W. F. Graham commented on the accuracy with which the temperatures in the furnaces mentioned by Mr. Nelson were maintained but endorsed Mr. Sherry's views on the use of the lead pot, saying that quenching and drawing in the lead pot give accurate results on forgings. In his opinion the variations in the Brinell hardness mentioned were functions of the carbon and the manganese contents; he thought that the percentage of these two elements must be given consideration and the drawing temperature varied accordingly. In continuing the discussion Mr. Nelson said that the manner in which the temperature is raised has a decided effect on the making of steel. In response to a question by H. J. Stagg as to whether the differences in the raw material could not be ascertained and used as a basis for predicting the results obtained, Mr. Nelson agreed that it is possible to detect the differences but could not state their effect. He added that steels of supposedly identical composition from different mills require different heat-treatments. In support of Mr. Nelson's last remark Mr. Dawe said that he had seen steel that was chemically and metallurgically correct that could not be hardened when first treated but that after gear-blanks produced from this steel had lain in the factory yard for 9 months satisfactory results were obtained. He believed also that the seasoning of gear-blanks in this manner would eliminate warpage in heat-treatment.

The need for good designing of malleable castings and the fact that better results can be secured by paying proper attention to the section of the castings were the two principal points brought out in the discussion of the paper on Pertinent Facts Concerning Malleable-Iron Castings, by Enrique Touceda. In answer to a question by F. P. Gilligan, who presided at the session, as to the willingness of automotive engineers to respond to requests from the foundries for changes in the design of parts for which malleable-iron castings are used, Mr. Touceda said that, while the willingness of engineers to respond to such requests had always existed, it had been particularly noticeable within the last two or three years.

Fuel and Engine Session

The paper on Manifold Vaporization and Exhaust-Gas Temperatures, by O. C. Berry and C. S. Kegerreis, was first on the program for the Fuel and Engine Session and was presented in outline by Mr. Berry. Most of the members who had manifested their interest by attending the Research Session gave evidence of a continuation of this interest by being present, and the representative audience was presided over by Chairman A. L. Nelson.

Stating that present internal-combustion engine fuel is too low in volatility for economical use and that this is the course of engine-maintenance troubles, Messrs. Berry and Kegerreis believe that, since it is not possible to obtain the more volatile grades in sufficient quantity, the only hope of remedying this condition is to learn how to use the heavy fuel, and that the most promising method of doing this lies in the effective use of heat.

As the experimental data regarding the best temperature at which to maintain the metal in a hot-spot manifold are meager and the range of temperatures available in the exhaust gases is narrow, the authors experimented in the Purdue University laboratory to secure additional data. Their paper presents a summary of the results.

They feel that the exhaust-gas temperatures are high enough for properly designed manifolds, together with thermostatically controlled carbureter temperatures, to make possible the satisfactory carburetion of fuels considerably heavier than the present "power" gasoline, without seriously limiting the power, efficiency or flexibility of passenger-car engines or causing any engine-maintenance troubles.

The paper by Thomas Midgley, Jr., and T. A. Boyd on Methods of Measuring Detonation in Engines[3] was read and commented upon by Mr. Boyd, who emphasized and amplified some of the statements contained therein. Among the points so treated were that three elements are of primary importance in a universal method for measuring the intensity of detonation. First, the method should embody a means for indicating the relative intensity of different detonation waves. Second, it should comprise means of integrating the intensities of individual waves over a period of time, and of yielding a numerical value that is accurate and can be duplicated when employing the same method. Third, a standard fuel should be used as a basis of comparison so that the results obtained can be repeated by different observers and under varying conditions. An amplification was made of the four different methods of measuring detonation that are considered in this paper, the listening, the indicator, the temperature and the bouncing-pin methods as described in Table 1, and the type of record that is possible in each case.

The paper on the Spectroscopic Investigation of Internal Combustion, by Thomas Midgley, Jr. and W. K. Gilkey, was enlarged upon by Mr. Midgley. It is designed to familiarize automotive engineers with the general subject of spectroscopy, pointing out the various methods that can be employed to determine the actual instantaneous pressures obtained in normal combinations, the temperature-time card of the internal-combustion engine and the progress of the chemical reactions involved in normal and abnormal combustion.

The subject of spectroscopy is outlined and explained first, illustrations being presented of different types of spectra, and spectroscopes and their principles are dis-

[3] See THE JOURNAL, January, 1922, p. 7.

cussed. The remainder of the paper is devoted to an outline of what the spectroscope can reveal about the nature of combustion.

The discussion that followed the presentation of each of these papers will be printed later in THE JOURNAL, and the papers by Berry and Kegerreis, and by Midgley and Gilkey also will be published therein. The discussion included an explanation by P. S. Tice of differences from some of the curves exhibited by Mr. Berry that he has obtained, and comments by Prof. R. E. Wilson regarding the subject of the end-point of fuels. Mr. Boyd answered the question as to how comparisons between detonation effects existent in different engines can be made by stating that this is accomplished by using a standard fuel for all such tests. Mr. Midgley gave further explanation of the different kinds and qualities of light in various portions of the spectrum, in answer to a doubt expressed by one of the speakers regarding the feasibility of using the spectroscope for investigatory purposes when pressure conditions are involved.

Passenger-Car Session

It is a fact to be deplored that all finite good things must, at some finite time, come to an end. In this connection and as this report of the 1922 Annual Meeting of the Society approaches its conclusion, we must record that although the Passenger-Car Session held on the morning of Jan. 13, 1922, was the last of all the successful events of this eventful week, it was by no means the least successful. The informative and exhaustive treatises by J. Edward Schipper and S. von Ammon and the most interesting and in many respects novel paper by Prof. A. Trowbridge were a guaranty of this; but, to clinch the argument in favor of this session with staggered copper rivets let through the fabric from both sides and holes cut-punched and staggered for more, Past-President H. W. Alden was chairman of the session.

The paper on Passenger-Car Brakes was read in outline by the author, Mr. Schipper. He stated that the problem of deceleration is just as important and necessary of solution as the providing of car-acceleration ability, and then gave a comprehensive survey of present braking practice, together with an outline of future braking requirements and possibilities.

Design factors are considered at length in this paper, as well as the subject of what constitutes uniform and effective braking-power, various illustrations and descriptions of different types of brake being included. Brake-actuating means, the calculation of brake-drum size, car-stoppage ability, brake equalizers and brake-linings are commented upon in some detail.

The future of brakes is discussed with reference to the use of the engine as a brake, four-wheel and front-wheel brakes, the servo principle of brake operation and various novel braking methods. A brief summary of what is considered good practice with regard to truck brakes is appended. In many respects this paper bears the same relation to the subject of brakes as a previous paper by Herbert Chase on Practice and Theory in Clutch Design[4] bears to the subject of clutches.

The Bureau of Standards has been engaged for some time in developing a standard method for testing brake-linings, as a result of the general policy of the Motor Transport Corps to standardize the materials used for automotive vehicles for Army service, and has been cooperating with the Society and the automotive industry in this connection. Although the work has not been completed, much information has been gained and the paper on Developing a Method for Testing Brake-Linings, written and presented by S. von Ammon, reports the progress that has been made.

The equipment developed and the methods used for both main and supplementary tests are described. Data are given regarding the coefficient of friction, as influenced by various factors. The endurance test, showing the comparative behavior of linings under conditions similar to those of severe service, is believed to be satisfactory as developed. Further work is necessary before recommending the conditions for the other test, intended to determine the relative endurance under ordinary or light service. In work done thus far with a cooled drum and over a very wide range of power absorption and speed, difficulties arising from the accumulation in the linings of particles of steel cut from the drum have persisted. Supplementary tests covering the tendency of a lining to stick when brakes are left applied on a hot drum and to ascertain the relative absorption of oil and water are described. The influence of oil and water on the coefficient of friction is shown.

In his paper on the Photographic Recording of Engine Data, Prof. A. Trowbridge, of Princeton University, states that until a few years ago he shared what he believes to be the general feeling among technical scientific men, that photographic methods of recording experimental data, such as pressure-volume variations in an engine cylinder, vibrations of shafting and motion or timing of valves, could not be rendered sufficiently simple to be reliable in the hands of the ordinary intelligent mechanic; but that an experience of 2 years in France during the war convinced him that photographic recording is the quickest, cheapest, most foolproof and cleanest method there is.

After illustrating and describing the camera and automatic devices that were developed for, and successfully withstood, war usage, Professor Trowbridge outlined many possible uses for this apparatus in the securing of engine data, especially with regard to securing data that ordinarily are obtained from high-speed indicators, and showed how the parts of an indicator-card that are on too small a scale for accurate interpretation can be enlarged or spread out by this photographic method to permit close analysis. It is planned to reproduce with his paper in an early issue of THE JOURNAL the lantern slides that he used.

The time for the discussion of these papers was very limited and very likely its subject matter can best be reserved for detailed publication, except to say that much interest was shown in the relative merits and demerits of using the engine of a car as a brake, and that attention was called to the fact that only 4 to 5 in. of pedal travel is available for all ordinary braking effects.

Comparisons are invidious, irrelevant and uncalled for. The 1922 Annual Meeting of the Society is recorded upon the pages of history as having maintained a high standard of excellence, with its attendant accomplishment of scientific progress and social enjoyment. We feel that at no time during the passage of this eventful week was our marshalled army of cumulative progressive automotive-engineering data in any danger of being called upon to surrender to our good old military friend, General Average.

Reduced Railroad Fares

Seven hundred and forty-nine reduced railroad fares were granted to members of the Society and those of their families who accompanied them to New York City.

[4] See THE JOURNAL, July, 1921, p. 39.

It is estimated that the average saving per person was $12, and the total saving about $9,000.

The Carnival

The Carnival of 1922 maintained in full measure the enviable reputation set by the unusually successful Carnivals of former years. The ballroom foyer of the Hotel Pennsylvania was transformed by scenic artists for the occasion so that it represented a bit of Coney Island set down in the heart of New York City. The man with the fortune-wheel and assortment of boxed candy was there in all his glory. The pop-gun shooting-gallery proprietor vociferously announced the possibilities of acquiring your favorite cigarette without cost; if your marksmanship met the test. The fortune-lady peered into the hollow of many masculine and feminine hands, predicting the destiny of the future and recalling milestones of the past. A line of the curious filed steadily past the crystal gazer in order that he might solve their riddles of the coming year or astound them with his familiarity with their most intimate thoughts. Free lollypops proved to be especially popular. Paper hats added color to the assembled picture, while horns, rattles and whistles provided the necessary clamorous background. The members who attended the Summer Meeting at West Baden were reminded keenly of the sad evenings at the establishment of the Brown family. The famous Keno Room was depicted faithfully in one of the halls adjoining the ballroom and there the Carnival Committee disposed of many attractive prizes at the will of the checkered card.

The dance in the main ballroom was the major feature of the Carnival of 1922, as in the case of its predecessors. Music of the present age and vintage was served to the trotters and steppers by a group of 12 exponents of modern ballroom symphony. The gentler sex were present in ample numbers, scintillating in the latest creations of the exclusive modiste. Dancing continued until the wee small hours when the barkers were silenced, Brown's lost its faithful adherents and all the Carnivalites pulled up stakes, unanimously voicing approval of the work of B. G. Koether and his associates on the Carnival Committee.

The Annual Dinner

Toastmaster Kettering said that the address of Arthur R. Marsh at the annual dinner was alone worth the trip of many members to New York City, and it was clear that the members in general agreed with him. The whole dinner was of a highly enjoyable and instructive nature. One pleasing phase was that Past-Presidents Vincent, Manly, Kettering, Huff, Dunham, Alden, Marmon, Coffin and Riker were seated at the speakers' table.

In remarks prefatory to introducing Mr. Kettering President Beecroft said:

We have reached what we might term a maximum of production, but we are yet far from the maximum of efficiency, from the maximum of economy and from the final word in the economic application of all the automotive equipment we are designing.

We hear talk about the saturation-point of the automobile or of the motor truck. I wish we could forget that and consider the saturation-point of transportation. We have not reached the point of saturation of transportation and there will be no saturation-point in any phase or department of the automotive industry until we shall have arrived at the economic saturation-point of automotive transportation. Reaching that economic saturation-point should be our objective.

I wonder whether we appreciate the position in which we stand; whether we appreciate how fortunate we are. We are the generation that has been handed literally the conquest of the air. What a coveted position in the history of the ages, with this last great, grand field of conquest placed on our lap! We can view other conquests in the transportation field in the same way. The burden that rests on our shoulders is correspondingly great.

REMARKS OF TOASTMASTER KETTERING

In taking command of the dinner, Mr. Kettering submitted as his uptodate version of the Grasshopper song the following:

> One gashopper cuts his price right under the
> other gashopper.
> Another gashopper cuts his price right under
> the other gashopper.
> They are only playing poker;
> They are all looking for the joker;
> And they are all going broker.

Continuing his narrative of current affairs he said that the engineering profession has been guided by people who have been especially ordained not to listen to anybody but themselves. Salesmen have become overnight engineers; advertising managers have made Ananias cry. He felt that it is time for the engineers to have an idea of their own and tell their executives and sales managers, as well as any others that need to be told, just what a good automobile is if in their peculiar position they should happen to know what one is.

The automotive industry is just as basic as the bread-and-butter industry. It has entered into our civilization fundamentally. It is a great transportation activity. If ever the engineer had a real problem, it is today in trying to find out what the simplest practical thing is that he can design and build that will do the thing he wants it to do.

The engineer must be very much closer to his management than he has ever been before. He has been regarded as a more or less eccentric individual, and perhaps there has been some foundation for that. However, whenever two people think each other eccentric, there is perhaps a middle-ground; and whenever a financier, manager or salesman tries to dominate an eccentric engineer without analyzing exactly what he is trying to do, maybe he divides the responsibility.

The automotive industry is bound to stay. We have not started it yet. It is less than a generation old. The same essentials prevail that have been before us for a long while. We have reached a condition of economic balance. We are in a period of intense competition. It is axiomatic in any business that competition comes only when progress stops. All industries must go through such periods when they involve great capital investment. It is difficult to make a change.

The Society of Automotive Engineers must set a new standard of economic values. The only reason we have a second-hand problem today is that our new cars are no better than our second-hand ones. If we could make new cars immensely better than our second-hand ones, there would be no second-hand business. We are "saturated" for the simple reason that we have not made enough progress. We are only 3 years away from the war. Attribute the condition to that while you have the chance.

In introducing Mr. Marsh, the principal speaker of the evening, Mr. Kettering assured the members that they were about to receive the most important and constructive message they had ever heard. Mr. Marsh's ad-

dress certainly added greatly to the considerable reputation that has been attained by S.A.E. Annual Dinners as occasions at which the true industrial keynote for the respective years has been struck. It is thought that in clearness, pertinancy and forcefulness Mr. Marsh's talk has been rarely excelled. Nothing could have been more timely in the present condition of the automotive industry. Nearly every passage of his remarks, which are given in full elsewhere in this issue of THE JOURNAL, is worthy of close study. He said that, considering the farmers alone, there are at least 9,000,000 people in the United States who cannot afford to *not* have automobiles. He gave as an analogy that in years gone by every farmer had to have a horse, no matter what his income was. The economic uses of motor vehicles of one kind or another are of predominant importance. The joy-riding days of the automotive industry, as well as of car owners, are over.

The work of the automotive engineers is going to become much more important. The situation is going to be different, and it will not be an easy one. The railroads reached a stage 25 years ago where they had to be kept alive by the work of the engineer. The engineers alone have saved the railroads from utter ruin. The automotive engineers must bear the brunt of the pressure that is inevitable from the competition that rises to greatest intensity when an enormous product is demanded from the factories, but not enough product to fill the factories to capacity.

Mr. Marsh's theme was, How Are We to Know When Business Has Turned the Corner? The first factor is that in the long run the only way in which goods can be bought is by goods. Fundamentally, both actual money and bank credit are nothing. It is not by money or by credit that Europe can buy our goods, or that we ought to sell goods to Europe. Europe must buy our goods with goods. When the German mark was at its lowest and most demoralized, Germany was the largest buyer of cotton and copper in the United States, and of wool and tin in London. She did this by producing goods and getting them out into the world.

In Great Britain at no time since the war has production been as much as 60 per cent of what it was in 1913, in spite of the fact that there are in England more workers than there were in 1913. Banking credit and restoration of exchanges can be discussed interminably, but the situation will not be improved until people go to work and produce goods wherewith to buy goods. In the United States there are millions of men who do not wish to produce goods upon terms which the world can meet—and every industry suffers. The American farmer says, I cannot and I will not buy under present conditions. As was stated by George E. Roberts at the annual dinner of the Society last year, the real root of our economic troubles is that the equilibrium, the balance, between the producing and the consuming classes has been turned topsy-turvy by what happened during and since the war. Turning the corner means getting back to that state of balance which was the result of three generations of gradual adjustment under the stress of competition. The problems are working themselves out by a process of grinding which produces suffering in every direction. The urban population has received nearly five times the income the rural population has received, and yet the numbers of the two populations are identical. There is today, as compared with 2 years ago, a shrinkage of at least $6,000,000,000 in the distributable income accruing to the urban classes and workers in the United States from the cotton user in the United States alone. There is the same sort of shrinkage of a relative degree in the case of copper, iron and steel products, and of many other finished commodities.

This is the principal factor to consider in determining whether business is actually at the point of turning the corner. There are many indications that alleviation is at hand, although these are rather obscure. The best omen for the future is that in Europe production and consumption are rising steadily. With goods, goods can be bought.

In calling upon B. B. Bachman, whose term as President of the Society began at the close of the meeting, Toastmaster Kettering expressed the appreciation of the members for the excellent service Mr. Bachman had rendered as chairman of the Standards Committee and as a member of the Council for several years. He said that the remarkable spirit of cooperation in the Society and the automotive industry will solve the transportation problems facing the industry.

PRESIDENT-ELECT BACHMAN

The pleasure and profit that I had in serving on the 1921 Council under Mr. Beecroft were so great that I regret keenly that his administration is closing. As I measure myself against him and his predecessors, I feel deeply the responsibilities that I shall assume tomorrow. I do not find my vocabulary adequate to express my appreciation to you who have honored me so signally. It is my hope that, with the support of the other members of the 1922 Council, and the assistance of the permanent staff of the Society under Mr. Clarkson, I shall be able to justify the confidence you have placed in me.

I wish to add a word of appreciation to the gentlemen under whom I have had the pleasure of serving on the Council, and particularly to those who intrusted to my care the Chairmanship of the Standards Committee. Next to the Presidency, I think that position bestows more honor upon the holder, as well as more responsibility, than any other. That I was able to hold it down at all is due entirely to the loyal support of those of you who have contributed to the work of the Committee so generously of your talent and time. I wish also to acknowledge the cooperation of the efficient organization under Mr. Clarkson's direction, without which the detail work of the Society would be hopelessly neglected.

As I review the history of the Society I am reminded forcefully that the reason for our continued existence and growth is that we have served. This may seem to be a rather flat statement, but I am inclined to believe that the general overlooking of this elementary function is at the bottom of a great many of the troubles the industry has undergone recently. There is an old saying that "He who does no more than he is paid for, is never paid for more than he does." I can hardly believe that this principle is applicable only in hastening the lagging footsteps of the office-boy. Rather, it is a homely way of telling us that whoever we are or whatever we are doing, the task and its completion in an honest way must mean more than the reward, if we are to succeed. Is it not possible that in recent years profits have loomed larger than service to the manufacturer and the merchant? Have not wages seemed of more moment than increased efficiency to the workman?

The more I have thought the more strongly I have been impressed by the fact that to progress in the times that are ahead of us we must get back to fundamentals and measure our plans and purposes by the plain and commonsense yardstick, Service. This it is my purpose to do to the best of my ability with your assistance during the

coming year. We must, if we are to continue our growth and maintain our prestige, serve our members, particularly the younger men; for upon the engineer rests a large responsibility in solving many problems that are spread over the road our industry must travel in the coming years. To meet these responsibilities we must widen our horizon continually. It is essential that there be brought into the engineer's mind and into the drawing-room and the laboratory a clearer conception of manufacturing and merchandising. In other words, we must be more than technicians; we must be business men and view our problems from the commercial as well as the technical side. I know of no better way in which this viewpoint can be developed than by the contact that active participation in the affairs of the Society provides. Those of us who have been fortunate enough to attend the meetings of the Society appreciate this thoroughly; but how about the hundreds of younger men who do not have this advantage? The activities of the Sections provide for them in some degree, but it is possible that more can be done along this and other lines if we put our mind to it.

I have heard the statement that we would be better off if the Society had fewer members at higher rates for dues. In other words, that we should be more exclusive, and the Society become a Hall of Fame open to only those who have arrived. I believe that we should bring more earnest young men together and grow with them as they grow. This is our foremost mission. Next to it is our responsibility to the industry in finding solutions for the problems that confront it. Of these there are many, relating to features of design, to production, and to use in the hands of the public. Some of these we are competent to deal with alone; on others, we can act only as assistants. I believe, however, that the enlarged character of our meetings, the increased scope of Section activities, the present stature of the Standards Committee and the growth of the Research Committee are facts in evidence that we stand ready and equipped to cooperate with the commercial organizations of the industry in any way they may desire.

Finally, what is our duty outside the immediate circle of our industry? I am becoming more and more of the opinion that there is a tendency in modern affairs to over-organization on every side. I hope I am not too narrow in this belief, but I cannot help feeling that, although these movements are often praiseworthy from the standpoint of the motives that lie behind them, they result in a lowering of efficiency and a delay in producing results. In the work of an organization such as ours the members can be called upon generally for a small proportion of their time; in most cases too small, however, for them to handle effectively any details. The result is that the details must be attended to by the permanent staff of the Society, the size of which is governed by its financial resources. Overloading this organization results in reducing the individual and collective efficiency. I believe that under the prospective conditions of this year we must fix the responsibilities in our own field firmly in our mind and attend to our own knitting.

The organization of the Administrative Committees of the Society for the coming year is complete; and a type of mind that would willingly go along with mine was not a qualification that controlled the selection of the members of these Committees. On the other hand, I hope to be able to benefit by their advice in guiding the affairs of the Society. But I hope that we shall be united in making the motto for the year 1922; Service.

CROWBARS AND ECONOMICS

VERY few people who are earning their living know much about the fundamental science underlying business. There are many business men who insist on their machine designers and their bridge designers being thoroughly well grounded in the theory of physics, yet these same men may hoot at the idea that there can be any sense to economic theory. They look on economics as nothing but a lot of fine-spun notions existing only in the heads of college professors. Even a good crowbar artist in a quarry might look on physics in the same way.

The business man is using economics every day. He may be a real artist with his economics, and not know much about fundamental theories of economics. But to the extent that he is successful in his business he has applied economic theory properly. To the extent that he has misapplied it he has failed to reap the full benefit of his tugging and sweating on his own crowbar, and even may roll his business boulder over on himself.

Every year Bradstreet's publishes figures classifying failures according to their causes, and these statistics show that only from 11 to 14 per cent of all these failures are due to causes over which the men who fail could have no control. Most failures were due to causes that lay in the control of the men who failed. They used their crowbars wrong and toppled their business boulders on themselves. It would seem that for the 87 per cent who fail some better use of the theory of economics would no doubt be of very considerable assistance.

Failures destroy wealth as much as fires do. Our failure loss runs considerably ahead of our fire loss in a year. Between the two of them it is estimated that we Americans are destroying at the rate of nearly $1,000,000,000 of wealth per annum right now.

Under a free competitive system, which seems to be about the only one the world can work under, every man is free to take his chance—and he should remain free, but others should not be called on to pay the cost of his ignorance. A large amount of futile effort is wasted by ignorant men in getting out their business boulders. Many who do not fail completely waste a tremendous amount of business effort in their work. Economic education is the only palliative for this waste.—E. F. Dubrul in *American Machinist.*

THE INTERNAL-COMBUSTION ENGINE

THE history of the internal-combustion engine is of much shorter length than that of the steam engine, for it was not until the latter had been in use for over 50 years that a successful prime-mover using gas was produced. The advance made in design since the first combustive free-piston gas engine was hailed as epoch-making is well illustrated in the present-day high-speed engine producing 1 hp. for each 2 lb. of engine weight. The improvements in design have been followed by a more general use until at present there are in the United States at least five times as much horsepower in internal-combustion engines as in steam turbines and steam engines. The enormity of power of the steam powerplants in any State is completely overshadowed by the horsepower of engines using liquid or gaseous fuel. Furthermore, the annual production of the internal-combustion engine is increasing much faster than is the construction of prime movers employing steam as the source of energy such as reciprocating engines and turbines.—*Power.*

How Are We to Know When Business Has Really Turned the Corner?

By Arthur R Marsh[1] Annual Dinner Address

In the highly complimentary introduction with which your toastmaster has favored me, he has perhaps omitted one of my more human qualifications. Coming from Boston is scarcely human; being a professor in Harvard is certainly not human; and what shall I say about being an editor? But in order that I may appear in a human light before you, I will venture to say before I begin my address proper that I am also a member of one of the best-known gambling institutions in New York or the Country—the New York Cotton Exchange. I say one of the best-known gambling institutions because the New York Cotton Exchange is commonly so designated through the South, in the halls of Congress and in various other influential quarters.

Some of you remember, no doubt, from the days of your childhood, that passage in Alice in Wonderland in which Alice tried to turn a corner and saw the corner perpetually a little ahead of her, but always just before she got there the corner straightened out and there was no corner to turn. I suspect that in truth we shall never know precisely when business turns the corner; that, after all, we shall go along the road seeing corners ahead which we hope to turn, but that, when we get there, we shall find there is no corner at all.

I am a little embarrassed by having been assured by your President and your Toastmaster that engineers in general do not care very much about economists or economics; that you do not know very much about economics and that you are not particularly interested in it. Perhaps I am doing these gentlemen an injustice in stating what they have said to me, but that at any rate was the impression I derived from what they said. I am therefore to tell from an economic standpoint, to a body of gentlemen who do not care about economics, when business has economically turned the corner, when there is no corner to turn.

I do not wonder much that a body of engineers, and particularly automotive engineers, should be a little doubtful about economics. You have not been paying much attention to the economists, but the economists have been paying a lot of attention to you, and some of the things they are saying about you, well, your own Toastmaster might have said them. That is as good a way of describing them as I can think of.

A few days ago I was reading the elucidations of an economist about the automobile industry. He has got you in very bad shape, in a very bad plight. He has discovered that nobody who has not an income of over $2,000 a year has any right to have an automobile. Having made that discovery, he set about finding out how many people there are in the United States who have an income of $2,000 or more a year. Naturally, he turned to the Treasury Department reports. He found that last year the number of persons who paid taxes on incomes of $2,000 or more was only 2,335,000. Then he found that last year there were 9,000,000 automobiles in the Country. 2,335,000 people in the United States whose means entitled them to have automobiles, and 9,000,000 automobiles; a really distressing condition of affairs.

Having got as far as that, the economist proceeded to discuss the question of saturation, which, I gather from what I have heard here tonight is a somewhat tender subject, and concluded that the United States is saturated to the extent of 5,000,000 automobiles at the present time.

If I may be flippant, I may remark that that is a good deal of a jag. "Now," says the economist, "with a population of 107,000,000 people, saturated to the tune of 5,000,000 automobiles, we have to add the further fact that 7,000,000 people in the United States are devoting themselves to the building of automobiles, to the manufacture of automobile parts, to the upkeep of automobiles and to the operation of automobiles." That leaves only 100,000,000 million people in the United States who are not engaged in the automobile industry. Again a rather serious state of affairs.

Then he goes further and remarks that the cost of these 7,000,000 people to the Country is 15.5 per cent of its entire income. In 18 years, such is the voracity of the automobile industry, it has arrived at a point at which it is absorbing 15.5 per cent of the entire national income. "Now," says the economist, "on the face of it, that cannot last; it is impossible that a state of affairs like that should persist," and he then proceeds to ask the question how soon the Country will get over what I have flippantly called "its automobile jag." In other words, how long it will be before it is desaturated. He arrives at the conclusion that in 1927, if you examine the population of the United States, you will find that it is desaturated of automobiles.

The case with motor trucks is a little better. The economist thinks that we shall be desaturated of them in 1924. But we have 5 long, weary years ahead of us, with a headache and all the unpleasant consequences of being over-saturated with automobiles.

Who Must Have Automobiles?

I will not try to analyze the economist's economics. That would occupy the whole evening. I shall simply remark in connection with what he has said that his premise that nobody in the United States who has not an income of $2,000 or more is entitled to have an automobile, is one that to a person like myself of farming antecedents is a little curious. I should say from what I know of the farming situation that there are at least 9,000,000 people in the United States who cannot afford not to have automobiles. In other words, we have, it seems to me, if I may venture to differ from my fellow economist, the situation in this Country, and it is not confined to this Country, it is world-wide, of millions upon millions of people who cannot afford not to have an automobile, no matter what their income is.

Of course, this is an old story. I remember that when I was a youngster the same thing used to be said about

[1] Editor, *Economic World*, New York City.

horses. Nobody could afford to have a horse unless he had such and such an income. Well unfortunately, a farmer, to take him alone, had to have a horse, no matter what his income was. In many cases the horse had a better income than the farmer had. But the farmer had to have the horse.

What has happened, only too evidently, it seems to me, if one examines the agricultural population of the world, is that there alone, quite without regard to the monetary terms of income, there are, as I said a moment ago, millions upon millions of people who as a matter of plain, economic necessity have to have an automobile.

Joy-Riding Over

There is, however, it seems to me, one rather interesting deduction to be made from what I regard as the gross error of my fellow-economist. It is a deduction which has already been intimated by your Toastmaster and by your President. The deduction is that the automotive industry has now come to a point at which the economic uses of automobile vehicles, of one kind and another, are of predominant importance. If I may put it briefly, I should say that the joy-riding days of the automobile are pretty nearly past, and perhaps I might add that the joy-riding days of the automotive industry are pretty well past. I think you will admit that the amount of joy-riding that has gone on in the automotive industry, taken altogether, has been fully as impressive as the joy-riding of the clerks and the typesetters and all kinds of people who like to go to Coney Island and go in a hurry and think they cannot afford to go for a 5-cent fare. The automotive industry has got to the point, then, at which economic considerations must be the predominant and determining considerations. Now this has been hastened, unquestionably very greatly hastened, by the economic occurrences of the past year or year and a half. The world-wide financial and industrial depression has brought out a truth in connection with the automotive industry that probably would not have been brought out for some time if we had continued in that exaggerated and artificial prosperity that we enjoyed, or thought we enjoyed, in 1919 and the first months of 1920.

The Engineer

That truth having been brought out, if you will permit me to say so, I believe you will find that the part of the automotive engineer will become from now on enormously greater than it has been in the past. In the past the automotive engineer has been a useful agent. He has been looked to as the man who provided the wherewithal for the joy-riding. From now on you will have a different situation, but that situation will not be an easy one. Unless I am mistaken, a stage has been reached in the automotive industry that is very much like the stage that was reached by the railroads 25 years ago, a stage in which the railroads kept themselves alive by what their engineers did for them, in which the railroads, subjected to, as it seems to me, very intolerable regulations of the Government in the matter of rates, had to do engineering marvels if they were to keep the breath of life in them.

The engineers have done that for the railroads in the past 25 years. Those of us who have had occasion to follow the accomplishments of the engineers in connection with the railroads are constantly amazed at what they have done. The sad thing about it is that the railroads have not got anything out of it at all as yet. Financially speaking, they are today in a worse condition than they were 25 years ago, in spite of all the engineers have done for them. All that can be said is that the engineers have saved them from utter ruin. I myself believe that the corner has been turned by the railroads and that they have a better day ahead of them, but it has been a desperate struggle and mainly a struggle of engineers.

Part-Capacity Production

You have ahead of you in the automotive industry something not unlike what the engineers have had in the railroad industry. You will have to work your very hearts out in the next 5 years, just to keep yourselves alive, because they will be hard years. I was impressed, in looking over statistics issued recently, by the fact that your production during 1921 was between 1,600,000 and 1,700,000 passenger cars and trucks, but that that production was 24 per cent less than the production of 1920. In other words, it was certainly 24 per cent less than your capacity.

Every economist knows that the bitterest times through which an industry passes are the times when production is from 70 to 90 per cent of capacity. Those are the times when competition is the most bitter, when prices irresistibly crowd down upon every establishment in the industry. It is more difficult to make any money in an industry when it is operating at 80 per cent of capacity than at any other time. When the operations of an industry are only 30 or 40 per cent of capacity, there is not much price-cutting; it is not worthwhile; it is evident to everybody that it is not worthwhile. But let the demand get up to 80 per cent and then every manager and director in that industry immediately begins to say to himself, "There is a lot of business passing, a lot of it; now if I can only get enough of it to fill my establishment, I shall get my overhead down and then I can begin to make money." The overhead, what I may call the doctrine of overhead, as an accounting proposition is like acid eating away prices when an industry is operating at 75 or 80 per cent of capacity.

So when I saw that during the past year the output of the automotive industry in this Country had been 24 per cent less than capacity, I should have known, without looking at a single advertisement, that there had been price-cutting in every direction in the industry. It always happens under such circumstances.

That is the kind of pressure you engineers will have on you. You will have the competition that arises in its greatest intensity when an enormous product is demanded but not enough product to fill all the establishments to capacity. It will be for you to work out the means by which you can meet this situation, the means by which you can gradually bring the automobile vehicle, whether a passenger vehicle or a commercial vehicle, into such nice adjustment with the economic needs of the communities of this and other countries that once more there will be a free flow of automobile vehicles to consumers; once more your capacity will be fully occupied and then once more you will begin to make a reasonable and comfortable profit.

But do not think for a moment that as a matter of economics you will not have a hard time of it, because you will. When I say this I know, of course, that I am talking to gentlemen who respond in their own mind to a demand of this sort. It is one of the honors of the engineering profession of the United States that it has perpetually done the impossible. There is no great profession in the United States of which it can so consistently be said that over and over and over again it has done the impossible, as the engineering profession, and I am sure that automotive engineers differ in no respect

from the great body of engineers of which this Country has such great reason to be proud.

But after all, I am not talking about my subject, "How We Are to Know When Business Has Turned the Corner."

I will give you only two or three rather simple tests that you yourselves can apply, if you follow the course of business, and by which you can arrive at a reasonably fair conclusion as to the moment from which there will be a steady onward, upward movement of all kinds of business.

Goods Bought Only With Goods

The first of these tests you will not find laid down in the economic textbooks, but it is an economic principle none the less; that in the long run, in the last resort, the only way in which goods can be bought is by goods. Goods are bought with goods and with nothing else. We all think of buying goods with money because we go through the form of paying cash or drawing a check; but, fundamentally, money is nothing; neither actual money nor that artificial money which we call bank credit. You can go on, I grant you, for a little while buying goods with actual money or with created money, banking credit, but you cannot go very long; you can gc for a year, perhaps for 2 years, but in the end you come back to the old inevitable truth that the only thing that will buy goods is goods.

Now the troubles of the world at the present time are generally painted to us by our bankers, who are chiefly heard as exponents of our situation, as due to demoralization of credit, of banking, of the currencies, of exchange, particularly the banking, the credit currency and the exchange of the countries of Europe. Our bankers tell us that if we, here in the United States, will only subscribe money enough to give Europe unlimited credit, Europe will buy our goods in unlimited quantity; our industrial activity and prosperity will immediately return and everybody will be happy. I regret to say that I think that that is one of the most pernicious doctrines of the present time. It is not by money or by credit that Europe can buy our goods or that we ought to sell our goods to Europe. Europe must buy our goods with goods; that is the only way she can buy them for long.

Buying by Germany

It is an interesting fact to one who bears that principle in mind that wherever you find in Europe people at work and producing goods, you find them buying goods, notwithstanding the condition of their credit, the condition of their currency or the state of their international exchange. The best illustration I know of this is the country that was our arch-enemy in war, Germany. Apparently, there is something about getting a licking that makes people ready to go to work; the Germans got a licking and they have gone to work.

Down in the gambling institution of which I am a member we hear every little rumor of coming financial trouble. One of the things that we heard much about for very many months is the awful depreciation of the German mark. The persistent depreciation of it we have heard of day-in and day-out as a reason why things were going to the bad very rapidly; and in particular the cotton business would suffer greatly and, most important of all, the price of cotton would decline.

Now it was a very curious fact that at the very time when the German mark was at its lowest and most demoralized, Germany was the freest buyer of cotton in the United States, of all countries in the world. I remember that on the day the German mark fell to its lowest price a friend of mine who is a large exporter of cotton said, "I do not know what to think of this thing. The mark has gone to pieces and nobody wants it and they all say it is going to nothing, but I have just made the best sale of cotton to Germany, on a better basis, that I have made this year to anybody."

I said, "How are you to be paid for it?"

"Paid for it? Check on a bank in New York; nothing could be better than that, could it?"

And it is a fact that has come home to us in the cotton business that Germany, with no credit, with a currency completely worthless, you might almost say, with exchange down to a perfectly ridiculous price, with all these handicaps, has been the largest buyer of cotton in the United States this year. That is not all; she has been the largest buyer of copper in the United States this year and she has been the largest buyer of wool in London this year and she has been the largest buyer of tin in London this year. I could name a dozen commodities of which she has been the largest buyer in the world, if we except the United States. And, mark you, Germany has not any money and she has not any credit. I say she has no money; you cannot call German marks money now. But she comes over here and she wants $1,000,000 worth of cotton and goes to a Cotton Exchange member and buys $1,000,000 worth of cotton and pulls $1,000,000 out of her breeches pocket, if that is a correct way of speaking. She wants copper and produces the cash and she wants these other things and produces the cash.

How does she do it? There is no question how she does it. She does it because she produces goods and because she gets those goods out into the world and because with those goods she can buy goods.

Idle Working People

Our English friends are feeling very much disturbed at the present time. As you know, they are talking about the necessity of a financial rehabilitation of the Continent of Europe. They tell us that there must be organized an enormous institution that will put the finances and the credit and the exchange of Europe upon a safe and sound basis, and Lloyd George has been as busy as he could be in the last week down at the Inter-Allied Conference at Cannes, working out a scheme, back of which, I may mention, stands the United States of America, with its assumed illimitable wealth, ready to put up the cash. With this institution Europe will once more be able to be a great market and in particular will buy the products of British industry and things will be very comfortable and very nice.

Then those of us who study the dry statistics of foreign trade all over the world come upon some curious facts. We find, in the first place, that these demoralized countries in Europe have been buying of Great Britain a larger proportion of British exports than they bought in 1912 and 1913, and that the United States of America, about whose credit I suppose nobody seriously doubts, has been buying less of British products than it bought in 1912 and 1913. On the face of those figures it would seem as though a rather expedient thing to do would be to get the United States buying. Perhaps the idea of the Cannes conference is to get *our* credit stiffened up so that we can buy.

The hitch is here: Lloyd George and many of the statesmen and financiers of England taught the working people of England, and I include among the working people of England not only the wage earners but also the managers of industry and the producers of England, that after the war they would work less and get more than

they did before the war. Consequently the British coal-miners are insisting that they shall work only 30 hr. a week and be paid four times as much as they were paid before the war for 54 hr. a week.

You find the same thing in the British iron and steel and cotton industries. When you study the statistics of British production and foreign trade, you find that at no time since the war has production in Great Britain been as much as 60 per cent of what it was in 1913, in spite of the fact that there are in England, according to their own official statements, more workers than there were in 1913, because there has been no emigration from Great Britain during or since the war.

British Ferrous-Metal Production

Then you come upon a marvelous condition of affairs. We will take the great iron and steel industry that, next to the cotton industry, is the greatest of the export industries of Great Britain. The normal production of pig iron in Great Britain is 750,000 tons a month. The normal production of crude steel, steel ingots and castings in Great Britain is 875,000 tons a month. What do you suppose the production of pig iron and crude steel was in June, 1921? Unless you know the figures, you cannot have the faintest idea of what they were. In pig iron, where there should have been a production of 750,000 tons a month, there was a production of 1500 tons. In crude steel, where there should have been a production of 875,000 tons a month, there was a production of 800 tons. Now just imagine the British industries, the engineering industry, the cutlery industry, the railroad equipment industry, the thousand and one industries that are dependent upon iron and steel as the raw material that they are to turn into products to send to the outer world wherewith to buy products, and think what it means to have the production of pig iron come down to 1500 tons in a month and the production of crude steel to 800 tons a month!

There is where the hitch is. That is why we are having trouble in selling our goods as freely as we should like abroad. They are not working; they are not producing; they are not making the goods that can be paid for goods; and we cannot sell goods unless other people make goods with which to pay for our goods.

You can talk about banking credit, you can talk about the restoration of the exchanges, you can talk about all those things that our financiers tell us about until you are black and blue in the face, and you will not improve the situation one iota unless people go to work and produce goods wherewith to buy goods.

Conditions in This Country

Gentlemen, I have been using as an example Great Britain, which I love and in which I believe with all my heart and soul. But I am sure that no one of you sitting here fails to realize that we have substantially the same situation right here in the United States. We have millions of men still who do not wish to produce goods upon terms that the world can meet, and because they cannot produce goods on the terms they want, they do not produce them at all, and because they do not produce them at all, every industry suffers. If those goods were produced, the products of other industries would be bought and paid for.

Sometimes a gambling economist like myself wonders at the things men say and do. We have here in the United States a large amount of industrial unemployment. We have had a Conference at Washington to discuss what should be done about it. We have considerable agitation in our States and in our cities, and our newspapers talk about it; we talk about public works and this, that and the other expedient to get rid of industrial unemployment. Yet at the very same time that we are doing this we are saying to the farmer in Iowa or Nebraska, "In 1913 when you wanted to buy a farm wagon we were glad to sell it to you for 200 bushels of corn; today we expect you to pay 750 bushels of corn for the same wagon." To the farmer in Kansas or Texas we say, "In 1913 we were glad to sell you a pair of shoes for a cowhide; today we expect you to give five cowhides for a pair of shoes." To the dairy farmer up in Michigan we say, in similar fashion, "In 1913 for four calfskins you could get as good a pair of shoes as anybody needed; today we expect you to pay 21 calfskins for a pair of shoes."

To come a little nearer home, we say to the farmer in Nebraska, Iowa, Illinois, "In 1913 we were glad to sell you an automobile that was pretty well adapted to your purposes for 1500 bushels of corn; we now expect you to pay 4000 bushels of corn for the same automobile."

The farmer says, "I cannot and I will not do it. There is no use talking to me about doing it; I will not do it and I cannot do it."

A friend of mine came back the other day from a trip out through Nebraska and surrounding territory. He said, "Heavens and earth, the clothes those farmers out there are wearing look like Joseph's coat of many colors." We said to them in 1913, "For 100 bushels of corn we will sell you a very good suit of clothes made in New York." Now we say, "We expect you to pay 500 bushels of corn for the same suit of clothes because our industrial workers in New York who make clothing insist that they must be paid 255 per cent more than they were paid in 1913."

The farmer says, "I get only 60 per cent of what I got in 1913. How can I, getting 60 per cent of what I got in 1913, give to a clothing maker in New York City 255 per cent more than he got in 1913? I cannot and I will not."

The farmer is coming in for a large amount of condemnation these days because he has what is called a bloc down in Washington, supposed to be working in his interests. We are told that that is class legislation and contrary to the spirit of our institutions, and I rather think it is; but that is not the essential point. The essential point is that when our shoemakers are ready to sell shoes to the farmer for the same number of bushels of corn as in 1913, the farmer will buy just as many shoes as he ever bought; when our clothing makers are willing to sell clothing to the farmer for the same number of bushels of wheat as in 1913, the farmer will buy just as many suits of clothes as ever he bought; when our agricultural implement makers will sell a farm wagon or a plow or a tractor to the farmer for the same number of bushels of wheat or of corn or pounds of beef or pork as in 1913, the farmer will buy just as many wagons and plows and tractors as he bought in 1913; but he will not buy them until that comes about. The same thing applies to your industry as to these that I have mentioned.

Return of Economic Balance Necessary

The clearest-headed economic thinker in the United States is, to my mind, George E. Roberts, vice-president of the National City Bank, who addressed you a year ago. Mr. Roberts has been calling attention for many months to the fact that there is a natural equilibrium or balance between the various producing and consuming classes in each country and between the producing and

consuming countries of the world, and that the real root of our economic troubles at the present time is that that equilibrium, that balance between the producing and the consuming classes, has been turned topsy-turvy by what has happened during and since the war; and that turning the corner means getting back to that state of balance or equilibrium which, from an economic standpoint, has resulted from three generations of gradual adjustments under the stress of competition.

Within reasonable limits, when the farmer in 1912 and 1913 exchanged wheat for shoes, for clothing, for an automobile, he made the exchange on a basis that represented approximately the same amount of labor, effort, capital employed, and the like, that was represented by the product that he bought. Today that is all upset and the first and most important test of a business entering upon a real, continuous and dependable course of activity and prosperity is a return to that equitable balance or equilibrium of which I have spoken.

One could wish that when this fundamental truth is so clear as it is to minds like Mr. Roberts' that the process might be worked out by the wit of man. You engineers, in particular, accustomed to problems that you sit down and tackle and work out by your brains, must say to yourselves 100 times, "Why in the name of heaven cannot we take this great problem and work it out with brains in the same way that we work out our problems?" Why it cannot be, no one can tell. Human nature is so curiously constituted, particularly mass human nature, that apparently a rational process of working out these problems is impossible; but do not think for that reason that they are not working themselves out, because they are. They are working themselves out by a process of grinding that produces suffering in every direction, but none the less they are working themselves out.

Urban and Rural Incomes

I have indicated in a general way one of the great inequalities existing at the present time by what I have said of the farmer and what he buys. That can be generalized, however, still more broadly and I may say that one of our great economic problems is the lack of equilibrium, economically speaking, between the agricultural population as a whole and the urban population. How many of you really understand how extraordinarily great that lack of equilibrium is? You know that the population of the United States is almost equally divided between urban dwellers and rural dwellers, urban industrial producers and agricultural producers, but do you know that according to the best information we can get, information that has been brought together recently in a wonderfully instructive book gotten up by a new society for economic research here in New York City, with the population of this Country equally divided, the national income was divided for the 10 years ended with 1918 in the proportion of 17 per cent to the agricultural population and 83 per cent to the urban population? The urban population got more than four times, nearly five times, the income that the rural population got, and yet the numbers of the two populations were identical.

That, gentlemen, is a state which is inequitable and cannot endure. The truth is that during the war period and since the war period our urban population, to use a slang phrase of my gambling institution, has been getting away with murder, but it is having a hard time now.

To illustrate how the thing is changing, I will simply take 1 lb. of cotton and tell you what was happening with it in 1919 and the beginning of 1920 and what is happening to it now. In the end of 1919 and the beginning of 1920 a cotton farmer in the South sold his pound of cotton for approximately 40 cents, which was regarded as an inordinately high price. That pound of cotton left the farmer's hands and immediately came into the hands of industrial and urban workers, managers, financiers and all the rest of us who live in cities.

First, the cotton was sent to a mill, we will say in Fall River, that manufactures what we know as grey goods, semi-finished cotton fabric, and the manufacturer in Fall River took that pound of cotton and turned it into grey goods, getting 6 yd. of grey goods out of the pound. Those 6 yd. the manufacturer sold to what we call a converter, an establishment that bleaches, dyes, prints and treats the cotton fabric to make coat-linings or curtains or a thousand and one things that you buy at a retail store.

The cotton manufacturer in Fall River sold the pound of cotton in the form of 6 yd. of cloth to a converter for 22½ cents per yd., getting $1.35 for the pound of cotton in the form in which he was through with it. The converter, in his turn, after having bleached, dyed, printed and finished the cloth, sold the goods to a jobber for approximately $1.75 for the 6 yd.

Then the jobber, in his turn, sold the goods to a retailer, one of our department stores we will say, and the jobber got about $2.25 for the 6 yd. Then the goods were in the hands of the retailer. Well, you know what the retailer did! He sold the 6 yd. of cotton cloth for about $4. I am giving you roughly the prices that we had all along the line in 1919 and the beginning of 1920.

In other words, between the farmer's 40 cents and the ultimate price of the cotton cloth made out of the pound of cotton, there was the difference between 40 cents and $4, or $3.60, and that $3.60 all went to urban and industrial workers. The railroad workers got the first hack at it; then it got to Galveston or Atlanta or Savannah, to a port, and the stevedores got a hack at it; the truckmen got a hack at it; the people that handled it in and out of the ship got a hack at it; then the steamship company; then it got here to New York City and the lightermen took another hack at it. The merchants all along the line were taking nice pieces out of it, and it went to the manufacturer in Fall River. The wages of the manufacturer's help had been raised 148 per cent; they took a good piece out of it. When the manufacturer was through with it, it went to the converter; his help had been raised about 180 per cent; they got a nice piece. And so, all along the line from the farmer's 40 cents to the $4 ultimately realized, one set after another were taking a fine bunch of picking out of this pound of cotton.

What is the situation today? The farmer in the South gets, we will say roughly, 20 cents per lb. for his cotton. It goes to the manufacturer in Fall River; he makes it into 6 yd. of cloth but, instead of being able to get 22½ cents per yd., the best he can do today is 6½ cents per yd.; instead of getting $1.35 for the pound of cotton, he gets about 39 cents. Then it goes to the converter and he, instead of being able to get $1.75, is able to get only about 60 cents. It goes from the converter to the jobber and he, instead of being able to get the price I mentioned, $2.25, is able to get only about 75 cents. It then goes to the retailer and the retailer, you will see if you will look at the advertisements in the papers, is no longer getting $4 for 6 yd. of cloth; he thinks he is doing very well if he gets $1.25.

The point I am coming to is that whereas in 1919 $3.60 was divided up along the line to urban and indus-

(*Concluded on page* 110)

Officers of the Society

AT the Annual Meeting of the Society held last month a President; a First Vice-President; five Second Vice-Presidents; and four Councilors, three of whom were elected for the full term of 2 years and one to serve for 1 year only, were elected; and the Treasurer was reelected. In addition to these officers, two of the three Councilors elected at the 1921 Annual Meeting and the last Past-President are voting members of the Council for 1922. Photographs of the men who will guide the work of the Society this year are presented on the following pages and their careers are outlined below.

B. B. Bachman

President Bachman was born Oct. 4, 1886, educated at grammar school, night school and under a private tutor, and started his business experience in 1900 as a tracer. The next 10 years were spent as tracer, detailer and designer with the Enterprise Mfg. Co., and the Falkenay Sinclair Machine Tool Co., both of Philadelphia, and the Autocar Co., Ardmore, Pa. His entire automobile experience has been with the last-named company, which was a builder of passenger vehicles until 1912 and has constructed commercial vehicles from 1907 to date. Starting with this company in February 1905, he became assistant engineer in 1909 and engineer in 1914.

Mr. Bachman was elected a Junior member of the Society in 1910 and transferred to Member grade in 1912. He is a member of the American Society of Mechanical Engineers, American Society for Testing Materials and the Institution of Automobile Engineers. When the Pennsylvania Section was organized he was one of the charter members and served as its first secretary. He was identified with the work of the Truck Standards Division in 1911 and has been Chairman of the Standards Committee since 1918. At present he is a representative of the Society on the American Engineering Standards Committee. He was elected to the Council in 1916 and again in 1918. In 1919 he was First Vice-President of the Society, and in 1921 Second Vice-President representing motor-car engineering. As a member of the Truck Standards Division Mr. Bachman participated in the formulation of the specifications for military trucks for the Quartermaster Department, and afterwards was engaged at irregular intervals in the design of Class B and Class A military trucks. In connection with the last named, he was chairman of the committee on design.

At the 1913 Annual Meeting Mr. Bachman presented a paper entitled Comparative Results with Solid and Pneumatic Tires on Light Commercial Vehicles, and at the 1914 Annual Meeting he treated the subject of Double-Reduction Live Axle. At the 1919 Motor Truck Meeting he gave an address on Pneumatic Tires for Trucks.

J. V. Whitbeck

First Vice-President Whitbeck was born May 28, 1882, at Sodus, N. Y. He was employed as a draftsman and designer by the H. H. Franklin Mfg. Co. from September 1904 to October 1906, when he entered the service of the Olds Motor Works as a designer. Leaving there in March 1907, he accepted a similar position with E. R. Thomas, Buffalo. In October of that year he was engaged as designer and checker by the United Spring Co., Buffalo. In 1908 he became designer, checker and experimental engineer with the Lozier Motor Car Co. Mr. Whitbeck was chief engineer of the Chandler Motor Car Co. from 1913 to February 1921, when he was elected president of the Cleveland Automobile Co., the position that he now holds.

Mr. Whitbeck was elected to Member grade in the Society on Oct. 18, 1912, and was elected a Councilor at the 1919 Annual Meeting.

F. E. Watts

Second Vice-President Watts, representing motor-car engineering, was born May 22, 1879, on a farm at West Falmouth, Me. He received his education in the common schools of Falmouth Township, and prepared for college at Greely Institute, Cumberland Centre. He attended the University of Maine and was graduated in 1901 with the degree of Bachelor of Science in Electrical Engineering.

His first position was that of tracer and draftsman for the Holley Motor Co., of Bradford, Pa., where he worked on motorcycles, air and water-cooled engines, light cars and carbureters. After remaining there for 6 months he left to enter the service of the Taylor Signal Co., Buffalo, as a draftsman on electrically operated railroad signals. In 1902 he secured his first position as a designer with the J. W. Ruger Co., also of Buffalo, builder of gas and gasoline engines and baking and candy machinery. After remaining there 15 months, Mr. Watts made his entrance into the automobile field by securing a position in the drafting-room of the Electric Vehicle Co., Hartford, Conn., where he remained for 2 years. In 1905 he became associated with the Eisenhuth Horseless Vehicle Co., Middletown, Conn., where he held the position of designer of automobiles and compound engines for 1 year, when he returned to the Electric Vehicle Co. In 1906 he severed connection with that company and went to Detroit as traveling representative and technical writer for the *Horseless Age*. At the same time Mr. Watts was engaged in consulting work on automobile design and did considerable research on air-cooled two-cycle engines. The year 1909 was devoted to the development of a rotary-valve engine and an automobile. In 1910 he entered the service of the Hupp Motor Car Corporation, as designing engineer, subsequently becoming chief engineer of that company, which position he still holds.

Mr. Watts became a Member of the Society in the spring of 1908.

O. W. Young

Second Vice-President Young, representing tractor engineering, was born at Chicago, in 1885. He attended the public schools and the technical high-school of his birthplace and studied for 1 year in preparation for the practice of mechanical engineering.

In 1905 he became a draftsman with the Western Electric Co., at Chicago, and was subsequently transferred to the engineering department. Mr. Young spent a year designing steam specialties and from September 1908 to June 1910 was associated with the Chicago Engineering Co., on development work. Relinquishing that connection he became associated with the Economy Motor Car Co., Joliet, Ill., as a mechanical engineer, this marking his entry into the automotive field. While associated with this company he designed a motor truck and also de-

B. B. BACHMAN

signed and built a light electric town-car. In November 1912 he accepted a position as engineer with the Minneapolis Motor Co., Minneapolis, manufacturer of motorcycles and light package-delivery cars, resigning in December of the following year to enter the service of the H. E. Wilcox Motor Co., also of Minneapolis. In August 1914 Mr. Young became associated with the McVicker Engineering Co., a consulting engineering organization, of Minneapolis, in the design and development of several light tractors. In March 1915 he entered the service of the Hyatt Roller Bearing Co., Chicago, in its tractor bearings division and has been associated with that company ever since. At present Mr. Young is engineering manager of the tractor bearings division.

He was elected to Member grade in the Society April 17, 1917.

V. E. Clark

Second Vice-President Clark, representing aeronautic engineering, was born at Uniontown, Pa., Feb. 27, 1886. He was educated at the Uniontown public schools and was graduated from the United States Naval Academy at Annapolis, Md., in 1907. When the battleship fleet of the Navy made its famous world cruise in 1907, 1908 and 1909, Ensign Clark was attached to the fleet, and in 1909 made another cruise to China and the Philippines. He was commissioned second lieutenant in the Coast Artillery Corps in 1910 and served at Boston, San Francisco and Honolulu for 2 years.

Lieutenant Clark became interested in aeronautics in the early part of 1912, when he took up the study of airplane design and in April 1913 he was transferred at his own request to the newly organized aviation section of the Signal Corps. He holds a pilot's license dated Nov. 4, 1913, which is one of the earliest granted in this Country. In September 1914 Captain Clark was ordered to the Massachusetts Institute of Technology to take a post-graduate course in aeronautical engineering, and was the first officer graduated from this course. Upon the completion of the course in 1915 he was immediately placed in charge of the San Diego, Cal., experimental and repair depot. In March 1916 he was transferred to the City of Washington as chief aviation aid to General Squier with the title of chief aeronautical engineer of the United States Army. Captain Clark was appointed a member of the National Advisory Committee for Aeronautics in 1916 and when the United States entered the world war he was the aeronautical member selected by the Aircraft Production Board to serve on the Bolling Mission that visited France, England and Italy.

He was commissioned a lieutenant-colonel on Aug. 5, 1917, and undertook the organization of the Army experimental air-station at McCook Field, Dayton, Ohio, where he was responsible for a large portion of the aircraft engineering design work, including the first all-American battleplanes. In March 1918 Colonel Clark was recalled to the City of Washington and during the summer of that year was in command of the air-service concentration camp and general supply depot at Morrison, Va. He was subsequently reassigned to the engineering division of the Air Service at McCook Field, where he remained as chief engineer in charge of airplane design until November 1920, when he left the Government service to become chief engineer of the Dayton Wright Co., a position that he now holds.

In the past year Mr. Clark carried to completion four widely different and remarkably successful original aircraft designs. These were a twin-float seaplane intended for timber cruising and aerial photographic work, a shipboard airplane for the control of gun-fire in naval engagements, a side-by-side training airplane for the Army Air Service and an airdrome-defense airplane.

Mr. Clark was elected to Member grade in the Society, Sept. 12, 1916. In conjunction with Capt. T. F. Dood and O. E. Strahlmann, Mr. Clark presented a paper entitled Some Problems in Airplane Construction at 1917 Annual Meeting In addition, he has presented three other papers before the Society: Types of Military Airplanes, at the 1918 Annual Meeting; Maintaining Airplane Engine Power at Great Altitudes, at the Aeronautic Meeting of the Society held at New York City in 1920; and Air Transportation and the Business Man, at the 1921 Semi-Annual Meeting.

C. B. Segner

Second Vice-President Segner, representing stationary internal-combustion engineering, was born at Lamar, Pa., July 29, 1871. His boyhood days were spent helping his father who operated a small planing-mill, an experience that doubtless developed his mechanical inclinations. In 1890 he became an apprentice in the bicycle factory of the Crawford Mfg. Co., Hagerstown, Md., and 2 years later was transferred to the tool-making department. While serving in the latter apprenticeship he studied mathematics and physics under a private tutor and also took a correspondence course in gas-engine design. In 1894 Mr. Segner was appointed assistant foreman in the tool-making department and 3 years later was promoted to foreman and given supervision over the designing and making of tools. Leaving the Crawford plant in 1901, when the bicycle business began to decline, he accepted the position of machine-shop foreman with the American Machine & Foundry Co., at Hanover, Pa.

In 1902, with his brother, H. H. Segner, and A. S. Dornblaser he organized the Domestic Engine Co. to build small engines for farm and domestic use. The following year Mr. Dornblaser's interest was purchased by J. E. Reisner, of Shippensburg, Pa. At that time the plant was moved from Hagerstown, Md., to Shippensburg, and the business incorporated as the Domestic Engine & Pump Co. With this change in the location of the plant the construction of farm engines was discontinued and the building of a complete line of portable direct-connected pumping and hoisting engines for contractors' use was undertaken. In 1916 Mr. Segner was promoted from superintendent to vice-president and general manager, his present position. He has either designed or supervised the designing of the engines built by this company since its organization.

He was elected to Member grade in the Society, Feb. 13, 1920.

Henry M. Crane

Councilor Crane was born on June 16, 1874. He received his education in private schools, with a final year at Phillips Exeter Academy, graduating in 1891. He was graduated from Massachusetts Institute of Technology in 1895 with the degree of Bachelor of Science in Mechanical Engineering and in 1896 with a similar degree in Electrical Engineering.

After graduating he joined the laboratory force of the American Telephone & Telegraph Co. in Boston and worked there 2 years. In 1898 he was transferred to the engineering department of the Western Electric Co. in New York City, where he worked first on the preparation of telephone switchboard installation specifications and later on the development of apparatus and circuits.

In 1905 he left the engineering department to become engineering assistant to H. B. Thayer, general manager of the company, and finally resigned from the company in 1906.

In 1906 Mr. Crane organized the Crane & Whitman Co. in Bayonne, N. J., for the development of gasoline automotive machinery and especially motor cars. This company later became the Crane Motor Car Co., and in 1914 was consolidated with the Simplex Automobile Co. He was president of the Crane Motor Car Co. and vice-president of the Simplex Automobile Co.

In 1916 the Wright-Martin Co. was organized and absorbed the Simplex company. Mr. Crane became vice-president in charge of engineering and remained in this position after the reorganization of the company as the Wright Aeronautical Corporation, about Jan. 1, 1920. He resigned from the latter company on March 15, 1920, and for the remainder of the year was not engaged in any regular business but did some consulting work. During the past year he has been engaged in the development of a new passenger-car, the powerplant of which is now undergoing road tests in an old chassis.

Mr. Crane has taken a prominent part in the work of the Fuel Committee of the Society, and is Chairman of its Research Committee and the Aeronautic Division of the Standards Committee. At the 1920 Annual Meeting of the Society he was elected Second Vice-president representing aeronautic engineering.

W. R. Strickland

Councilor Strickland was born in 1875 at Cincinnati. He received his education at the Chicago Manual Training School and at the Massachusetts Institute of Technology from which he was graduated with the degree of S.B. in 1898. Immediately after graduation he entered the Navy as an assistant engineer with the rank of ensign and served at the Mare Island Navy Yard on the Pacific Coast and in the Hawaiian Islands on the U. S. S. Bennington during the Spanish-American War. Until September 1899 he was employed as a draftsman by the Blake Pump Co., Cambridge, Mass., and the Buckeye Engine Co., Salem, Ohio. From September 1899 to January 1901 he was a designer of electric traveling-cranes and chief engineer of the Case Mfg. Co., of Columbus, Ohio. At that time he became interested in railroad work, entering the service of the Colorado Fuel & Iron Co., Denver, Col., where he was engaged in railroad location work in connection with the opening up of coal mines and marble quarries. In 1902 he became associated with the New York Central and Hudson River Railroad on railroad location and construction, general engineering, maintenance, bridge and building work. In 1904 he was assistant secretary of J. G. White & Co., New York City, and was superintendent of construction on hydraulic and electric development at San Juan, P. R., leaving there in February 1908. In July of that year he secured the position of mechanical engineer and assistant manager of the Detroit plant of the American Radiator Co. and had charge of the operation and improvement of the continuous molding plant and machining department. In 1911 he became assistant engineer with the Peerless Motor Car Co., Cleveland, Ohio, where he was engaged in the perfecting and developing of four, six and eight-cylinder engines and truck and car chassis with bodies and fittings. He was made chief engineer of this company in 1913. He resigned this position last fall.

Mr. Strickland was elected to Member grade in the Society Jan. 5, 1912. He served as Treasurer of the Cleveland Section for the administrative year 1916-1917 and was elected Chairman of the Section the following year. Last year Mr. Strickland was Vice-Chairman of the Standards Committee, Chairman of the Ball and Roller Bearings Division of that committee, and Chairman of the Sectional Committee on Ball Bearings of the American Engineering Standards Committee.

C. F. Scott

Councilor Scott was born at New York City on May 30, 1886. He prepared for college at the Haverford School, Haverford, Pa., for 4 years and was graduated from the mechanical engineering course at Haverford College in 1908.

Following his graduation he entered the service of the Sprague Electric Works in the engineering department. After serving 1 year as a designing engineer he was appointed commercial engineer of electric motor and control applications. He has been identified with the development and application of the electric dynamometer almost from its inception in 1909. In connection with his work on dynamometers Mr. Scott specialized for 2 years in the adapting of the electric dynamometer to testing automobile engines by a thorough study of the internal-combustion engine. He developed and installed the first electric dynamometer for testing a complete automobile chassis.

Mr. Scott was elected to Junior grade in the Society, Oct. 24, 1911, and was transferred to Member grade, Sept. 11, 1912. He was elected Chairman of the Metropolitan Section in 1918 and automatically became vice-chairman the following year in accordance with the provisions of the Section constitution. He was a member of the Society Nominating Committee, representing the Metropolitan Section, in 1918 and 1919, and was secretary of the committee in the latter year, and a member at large of the 1920 committee. He has been a member of the Meetings Committee of the Society since 1919 and during the past year served as its chairman.

Lon R. Smith

Councilor Smith was born at Brownsburg, Ind., Dec. 24, 1876. After being graduated from high school, he spent 4 years at pattern-making and 3 more at die-sinking. Since entering the service of the Motsinger Device Mfg. Co., Pendleton, Ind., as superintendent in 1903, Mr. Smith's experience has been confined to the development of ignition, carburetion and engines. In 1907 he became superintendent of the magneto factory of the Henricks Novelty Co., Indianapolis, and from 1908 to 1910 was a salesman for that organization.

In March 1910 he was appointed Western representative of the Eisemann Magneto Co. and as such represented it in all of the United States west of Buffalo with the exception of Michigan and Wisconsin until the fall of 1916. At that time he became sales manager of the engine department of the Buda Co., Harvey, Ill. He left that company in June 1919 to accept the position of vice-president, directing sales and advertising, with the Midwest Engine Co., Indianapolis.

Mr. Smith was elected to Member grade in the Society in June 12, 1911, and was Chairman of the Indiana Section in 1915 and 1916, and was reelected chairman in the spring of 1921. He was elected Treasurer of the Mid-West Section in 1918.

W. A. Brush

Councilor Brush was born at Detroit, Nov. 9, 1872. He was educated in the high school of his birthplace

and also pursued some independent courses of instruction. Mr. Brush has been connected with the sales department of the Packard Motor Car Co., and was formerly head of the technical department of the Buick Motor Co., Flint, Mich. Together with A. P. Brush he organized the Brush Engineering Association at Detroit, to give technical advice to motor-car builders. He has been business manager of that organization since 1913.

Mr. Brush was elected to Membership in the Society January 1914, and has taken a prominent part in the affairs of the Detroit Section, having served as its Chairman. He has also rendered the Society valuable service as Chairman of its Membership Committee.

Francis W. Davis

Councilor Davis was born at Philadelphia in 1887. His first business venture was at the age of 17, when he managed a motorcycle agency and had charge of a small machine-shop which specialized in repairing automobiles and motorcycles and in experimental work. From 1906 to 1910 he attended Harvard University and studied mechanical engineering with particular reference to steam and oil engines. He was graduated in 1910 with the degree of Bachelor of Science.

Upon leaving college he entered the service of the Pierce-Arrow Motor Car Co., Buffalo, and took a course in the various departments of the factory. He was then placed in the experimental department and afterward transferred to the sales department as a sales engineer. In 1915 and 1916 Mr. Davis was consulting engineer on motor trucks for the British Admiralty and War Office. In this position he had to do with the selection of the equipment, its inspection, the training of the personnel, the establishment of repair and maintenance facilities and the operation of the equipment overseas. He returned to the Pierce-Arrow Motor Car Co. in 1916 as assistant chief engineer of the truck department and since that time has been truck engineer and consulting engineer of the truck department, in charge of design, experimental work, testing and quality, his present position.

Mr. Davis was elected a Member of the Society in 1916. He is a member of the Truck Division of the Standards Committee, the Truck Standards Committee of the National Automobile Chamber of Commerce, the Permanent Committee of Washington Highway Transportation Conference, and served as Chairman of the Society's Committee on the Science of Truck Operation.

Charles B. Whittelsey

Treasurer Whittelsey has been connected with the Hartford Rubber Works Co. since 1901, beginning as its purchasing agent. In 1905 he was made assistant to the general manager, in 1906 superintendent, in 1911 secretary and factory manager, in 1915 vice-president and factory manager, and in 1916 president and factory manager. He has served as president of the Hartford Chamber of Commerce and of the Hartford County Manufacturers' Association.

Mr. Whittelsey was elected to Membership in the Society in 1910. In 1916 he was elected a Life Member. He was a member of the Standards Committee for several years, beginning in 1911, and served as chairman of the Tire and Rim Division in 1918 and 1919. Mr. Whittelsey was a member of the Council in 1912 and 1913, and was elected Treasurer in 1918 and reelected each year since. At the 1912 Annual Meeting he delivered a paper on Solid Motor Tires, and at the 1915 Annual Meeting presented a paper entitled The Pros and Cons of Tire Inflation.

David Beecroft

Past-President Beecroft was born in 1875 at Marnock, Ont., Canada. He graduated from the Barrie Collegiate Institute. Beginning in 1895, he was an instructor for 6 years at a St. Thomas, Ont., school, being connected also with the editorial department of the *St. Thomas Daily Times*. Leaving St. Thomas in the summer of 1901, he was engaged by the *Chicago Daily News* as an advertising solicitor.

In 1902 he became editor of the *Automobile Review*, a weekly publication. In 1904 Mr. Beecroft was assistant editor of *Motor Age*, of which he became editor in 1907. In July 1911 he undertook, in addition to the *Motor Age* work, the position of editor of *The Automobile*. In November of that year he became also editor of *Commercial Vehicle*, and in February 1914 he took a similar position with *Motor World*. At the present time he is directing editor of the Class Journal Co., New York City.

Mr. Beecroft has been a pioneer in automobile contest work, having drafted the first stock-car racing rules and been closely identified with the American Automobile Association Contest Board for many years.

Mr. Beecroft became a Member of the Society in 1911 and has served on the Council for 5 years. He has been a member of the Meetings Committee for 6 years and its Chairman for 5 years.

Coker F. Clarkson

Secretary and General Manager Clarkson was born at Des Moines, Iowa, in 1870, and was graduated from Phillips Exeter Academy in 1888. In 1889 he was in Government service in the Post Office Department. He was graduated from Harvard College in 1894, pursuing post-graduate work there for the next 2 years. He was next engaged in connection with the installation of an underground telephone system in Philadelphia for 2 years, after which time he moved to New York City and spent several years in work on technical, legal, patent, laboratory and automobile subjects. From 1905 to 1910 he was connected with the Association of Licensed Automobile Manufacturers, as secretary of its Mechanical Branch, publicity manager and assistant general manager. During this time he was the editor of the A.L.A.M. Mechanical Branch Bulletins and of the A.L.A.M. weekly digest of current technical literature.

Mr. Clarkson has been Secretary and General Manager of the Society of Automobile Engineers and of the Society of Automotive Engineers since 1910.

During the war Mr. Clarkson was associated with the Council of National Defense, and served as a member of the automotive products section of the War Industries Board and of the International Aircraft Standards Board.

SPECIAL NOTICE

New Policy with regard to distribution of the

Transactions

and the

Membership Roster

FOR some time past there has been considerable discussion among members and the officers and councilors on the question of eliminating the more or less unnecessary expense in the issuance and distribution of publications of the Society, including cases where there is duplication of the printed matter. In this connection it is felt that approximately $15,000 can be saved annually in the printing and delivery of the TRANSACTIONS, and that this $15,000 can be used to much better advantage in broadening the Research and Standards work of the Society. The consensus of opinion among the Officers and the Council is that the greater part of the membership will not object to the transference of these available funds for the purposes above mentioned, if the TRANSACTIONS are made available at a nominal cost to the members who want them.

A resolution was therefore passed at the organization meeting of the 1922 Council for the purpose of eliminating the greater part of the expense of printing and mailing the TRANSACTIONS by making them available to members at $2 per part, there being two parts in each volume of annual TRANSACTIONS as now issued.

Practically all of the material contained in the TRANSACTIONS is preprinted in THE JOURNAL of the Society. It is therefore possible for members who do not wish to buy the TRANSACTIONS to save their JOURNALS for reference purposes. However, it would hardly pay a member to have his JOURNALS bound in preference to buying the TRANSACTIONS, because the cost of binding per volume would probably be more than $2.

Sufficient notice will be given in advance of printing so that all members who wish the TRANSACTIONS can get their orders in before the editions go to press.

Membership Roster

With regard to the Membership Roster, it was decided to eliminate the Company List and the Geographical List, thereby reducing the expense about one-half. In the future the Roster will contain an Alphabetical List only, and as a further measure of economy it will be sent to members only on request.

The Roster is now in process of manufacture. An order blank was sent out recently with one of the Chicago Meeting Bulletins. You are urgently requested to fill it out and return it to the office of the Society at once. Orders will be honored up to March 1, 1922. If you have not received or have mislaid the blank sent you, please use the blank printed on page 110 of this issue of THE JOURNAL.

IMPORTANT NOTICE

Do you want a Membership Roster?

If you wish to have your name and address correctly recorded in the 1922 Roster, please fill in, sign and return the attached blank at once.

Rosters will be sent only to those members who request them (See special notice on page 109). Your order must be received in the Society offices on or before March 1, 1922.

Name of company with which you are connected

....

Address of company

....
(Street and Number) (Town) (State)

What is your position or title? (State fully)

....

Where shall we address your mail?

....
(Street and Number) (Town) (State)

Of which Section are you a member?

....

I Do / Do Not } want a 1922 Membership Roster

....
Date (Print name in full)

Fill in on typewriter if practicable.

....
(Signature)

HAS BUSINESS REALLY TURNED THE CORNER?

(*Concluded from page* 101)

trial workers of one kind and another, today barely $1 is divided up among them. In other words, there is a shrinkage in what the urban workers and dwellers are getting out of that cotton of not far from $2.50.

In 1919 the United States used 3,000,000,000 lb. of cotton. Take a pencil and figure on that. There is a shrinkage today of at least $6,000,000,000 in the distributable income going to the urban classes and workers in the United States from the cotton used in the United States alone, as compared with 2 years ago.

Do you wonder that many people who would like to buy automobiles cannot buy them? Think of the people who are being hit by that; think of the people who have lost their jobs altogether because of it. What is true of cotton is true of copper; true of the products of iron and steel; true of any number of commodities turned into finished products by the various processes of manufacture.

The urban income of the United States has been squeezed I do not know how many billions of dollars in the last 2 years, and it is by that process that this readjustment that I have described as necessary and inevitable is actually coming about. Right there is to be sought the real reason for industrial unemployment in the United States. Does anybody doubt that, if it were possible to give every class of persons in the United States the same quantity of goods that they were taking in 1912 and 1913, there would be any unemployment in the Country to speak of?

What applies here applies also to Great Britain and her business on the Continent. Her exports today are running about 40 per cent in volume of what they were in 1913, and there is only one way in which they can be brought back and that is by bringing the prices down to the conditions of the classes of people that have to buy.

I think I have given you the main test that any one of you can apply to determine when business is actually on the point of turning the corner. I want to say this before I close. There are very many signs of a rather obscure kind, particularly in Europe, that the new situation is actually coming about. There are many signs in Europe that production and consumption are steadily rising. That is the best omen for the future that I know of, for, with goods, goods can be bought.

Research Information Service

A STRIKING illustration of the probable cost of *not* having research information readily and fully available is to be found in a statement of President Pritchett of the Carnegie Foundation for the Advancement of Teaching in which he reports that, on a visit in 1913 to the German Imperial Research Laboratories at Grosslichterfelde, he was informed that 80 *per cent* of all the problems sent to that laboratory and supposedly demanding experimental research were answered from their card-catalog of research information.

If any such percentage of proposed research undertakings in this Country is unnecessary because of previous work, information to this effect will result in aggregate savings out of all proportion to the time and cost of making the information available. Moreover, the ultimate object of the Society's Research Department, which is to secure through concerted effort along research lines more reliable technical information for the benefit of the industry, and to make this information more readily available to those interested in automotive problems, cannot be attained without first collecting the best possible information as to what has been accomplished and is now under way in the way of research applicable to our industry. To be sure, much of the information that is needed is in print. The collection of such information is merely a matter of time and patience, and an immense saving in both can result from a collection of this information by the Research Department for the benefit of the individual engineer. Much of the valuable information, however, is not in print, but is in the records of researches not yet published; in the back-files of laboratory notes and in the memories of men who have put in the time and energy necessary to solve some problem, perhaps in an emergency that has long passed, but which may arise for some other engineer.

Nor does even this cover the field of useful information as fully as it should be covered. Sometimes the most useful information is how *not* to do a thing. Information on the negative results or experimental failures seldom gets into print and not often into records. Nor do the plans and ideas for researches proposed or in progress become matters of record. The Research Department wants to make the fullest practicable use of such information by having records on file of not only what has been accomplished but also what general problems the various men and laboratories are interested in. When several members are interested in the same problems, they may find it very much worthwhile to work together. We

---

ENGINE
- Structural problems.
- Carbureters and intake systems.
- Pressure and temperature cycles and measuring instruments.
- Friction losses.
- Exhaust system and mufflers.
- Cooling system, fan efficiencies, etc.
- Vibrations and balancing.
- Performance of complete powerplant units.
- Starting in cold weather.
- Exhaust-gas analysis.
- Combustion-chamber design.

CLUTCHES
- Structural problems.
- Materials, facings, etc.
- Methods of test.

TRANSMISSION
- Structural problems.
- Efficiencies and performance characteristics of sliding gear transmission.
- Lubrication and lubricants.
- Causes of noise.
- Other types of transmission.

REAR AXLES
- Structural problems.
- Efficiencies and performance characteristics.
- Brake systems and lining materials.

CHASSIS
- Structural problems.
- Performance.
- Steering systems.
- Four-wheel brakes.

BODY
- Design and structure.
- Painting and finishing.
- Wind-resistance.
- Causes of noise.

ASSEMBLED VEHICLE
- Tests of performance.
- Relation of weight and fuel economy.
- Comparative deterioration with pneumatic and solid tires.

FUELS AND FUEL ECONOMY
- Effect of fuel characteristics on economy.
- Mixture ratios required for economy.
- Physical and chemical properties of fuel.
- Permissible cylinder pressures.
- Phenomena of combustion.
- Effects of turbulence.
- Blended fuels—alcohol, benzol, alcogas, etc.
- Addition of water vapor and steam to mixture.
- Fuel-savers.
- Carbon formation and its disintegration or removal.
- Ignition-point of gaseous mixtures under different pressures.

LUBRICATION
- Lubricating systems.
- Laws of lubrication of bearings.
- Mechanical efficiencies.
- Rates of wear.
- Carbonization.
- "Body" of lubricants.
- Crankcase dilution.
- Contamination of oil by hydrocarbon fuels.
- Reclamation of oil.

ELECTRICAL SYSTEMS
- Lighting generators.
- Starting problems.
- Storage batteries.
- Headlamps and glare.

MISCELLANEOUS MATERIALS
- Special steels.
- Castings of iron and steel.
- Structural uses of light alloys.
- Paints and varnishes.
- Upholstery materials.
- Rust prevention.
- Metal plating.
- Bearing metals.
- Methods of detecting flaws in metals.
- Valve steels.
- Die-castings.
- Anti-freeze compounds.
- Hysteresis in metals.

MISCELLANEOUS PROBLEMS OF DESIGN
- Design and performance of gears.
- Dynamics of spring suspensions.
- Theory of wheel design.
- Balancing and harmonic vibration.
- Gyroscopic effects.

TIRES
- Tire efficiencies and methods of test.
- Effects of vehicle design on tire wear.
- Specification for rubber used in tires.

ACCESSORIES
- Piston-rings and pins.
- Speedometers.
- Fuel flow-meters.
- Time-pieces.
- Warning signals, etc.

MOTOR TRUCK PROBLEMS
- Structural problems.
- Road resistance.
- Grade resistance.
- Analyses of operating costs with relation to class of service and class of truck.
- Impact tests on roads.

TRACTOR PROBLEMS
- Structural problems.
- Performance and efficiencies.
- Air-cleaning.
- Oil dilution.
- Use of heavy fuels.
- Efficiencies of implements.
- Cooling fans and radiators—special.
- Overturning.
- Economic sizes of tractors.
- Cost analyses.

AERONAUTICS
- Aerodynamics of airplane structures.
- Navigation instruments and navigation.
- Relation of flying speed to landing speed.
- Multiple-engine problem.
- Propeller speeds and gear reduction.
- Radiator efficiencies.
- Fire hazard.
- Metal construction of planes.
- Materials of construction.

TOPIC CARD PREPARED BY THE RESEARCH DEPARTMENT

are referring now to fundamental researches rather than to development problems, which latter the Department does not wish to include.

As a first step in securing information as referred to above, letters have been written to all research laboratories and to such engineers as can be reached, requesting information that will serve as a preliminary survey of the present research situation. After the replies to these inquiries have been studied, they will be supplemented by personal visits to the laboratories in which active work is in progress.

The collection of this information will be of direct value to the individual engineer only so far as he makes use of it. To make the information as useful as possible, the Department has prepared a simple subject-index which is reproduced on this page. If you have not replied to a special letter from the Department regarding research information, or even if you have done so, and are interested in receiving from or in supplying to the Department research information along any of the lines indicated in the topic card or along any other lines, please write us accordingly.

The general aims and objects of the Research Department have been described so fully in previous issues of THE JOURNAL that more is hardly necessary. Our industry, like most others in the United States, has in the past underestimated the importance of fundamental research compared with development and sales practice, and it is to remedy this condition that the Research Department has been established. The Society is not alone in recognizing that the future development of industry in this Country is certain to be on a basis of keener competition with other nations and to require on our part more general application of fundamental scientific and technical information, the result of fundamental research. The demand for men who have been trained in fundamentals and in research methods has come to far exceed the supply even under present conditions when there are in general more men in search of employment than there are positions available.

The Research Department hopes to be of maximum value to the members of the Society and to the industry in increasing the efficiency of the research facilities that we have available. Such a result can be accomplished only with time and cooperative effort. We trust that you as members of the Society will remember that the research information service is being developed for your use, that its success depends upon both giving and receiving information and that you will both give and receive your share.

SULZER MARINE DIESEL ENGINE

RECENT developments have shown that the comparative failures of the early two-cycle marine Diesel engines, built some years ago, were not due to inherent defects in the principles involved, but were the results of unsatisfactory, yet remediable, features of design. It is now agreed almost universally that the valve scavenging engine is unsatisfactory for marine work, and it is significant that in the four leading types of two-cycle engine, the Sulzer, Doxford, Camellaird-Fullagar and Polar, port scavenging is employed. By this means the formation of cracks in the cylinder covers has been entirely eliminated, and that was one of the chief difficulties encountered in two-cycle marine engines before the war.

The Sulzer engine was one of the first in which port scavenging was employed, but the designers rapidly came to the conclusion that if the best results were to be achieved it was not desirable that free scavenging through ports uncovered by the piston in the course of its stroke should be adopted. In other words, although valves in the cylinder cover were to be avoided, some means of controlling the admission of the scavenging air through the ports at the bottom of the cylinders was essential. Naturally, with a single-piston engine, such as the Sulzer, it is much more difficult to obtain effective scavenging than in an opposed-piston type like the Doxford, in which the scavenging air may sweep right through the cylinder from the bottom to the top, and in which, moreover, the exhaust ports may be uncovered before the scavenging ports, thus allowing the pressure in the cylinder to drop to a very moderate figure before the scavenging air is admitted.

The builder of the Sulzer engine overcame the difficulty that thus presented itself by the adoption of two rows of scavenging ports, one vertically above the other and each occupying about half the periphery of the cylinder. The top row of ports reaches well above the top of the exhaust ports, and both sets are in communication with the main horizontal scavenging air trunk, which runs the whole length of the engine, and through which the air is delivered from the scavenging pump. While, however, the bottom row is in unobstructed communication with the scavenging trunk and allows air to enter the cylinders as the ports are uncovered by the piston, admission of air through the top row of ports is controlled by a rotary valve within the scavenging trunk. These rotary valves, there is one for each cylinder, are operated from a common shaft deriving its motion from a vertical shaft at the after end of the engine that drives the camshaft at the top of the engine. The pressure of scavenging air is low, under 2 lb. per sq. in., so that there is no trouble in maintaining the tightness of the valves, which might be a difficulty were the pressures employed for this purpose materially higher.

The result achieved by this arrangement is easily understood. The operation of the valves is controlled so that no scavenging air enters through the upper row of ports until the piston has nearly reached the bottom of its stroke. In the meantime the exhaust ports have been uncovered, the pressure in the cylinder has fallen and the admission of scavenging air through the bottom row of exhaust ports has commenced. After the piston has covered the exhaust port on its upward compression-stroke the upper set of scavenging ports remains open, and as scavenging air continues to enter the cylinder a very efficient supply is insured. The claim that this system conduces to low fuel-consumption appears to be borne out by official tests, for as low a figure as 0.418 lb. per b. hp-hr. is attained with a 1250-b. hp. engine driving its own auxiliary pumps. This is very little in excess of the consumption with normal four-cycle engine design. It is worthy of note in this connection that the Ansaldo San Giorgio Co. of Turin, which is building two-cycle marine engines with port scavenging, prefers to control the admission of the whole of the scavenging air and to have only one series of ports for its admission.

The Sulzer engine has a particular interest for English engineers and shipowners, since its construction has now been actively taken up by four prominent marine engineering firms, namely, Armstrongs, the Wallsend Slipway & Engineering Co., Denny Bros., and Alexander Stephen & Sons. Its application to marine work is therefore likely to be extensive, and it is noteworthy in view of the discussion that is now so frequently heard concerning the possibility of a shortage of oil fuel that the builders of the Sulzer Diesel engine claim that it will run satisfactorily on fuel oil such as is burnt under boilers. The consumption when using Mexican fuel oil is 0.447 lb. per b. hp-hr. against 0.418 lb. with gas oil, the thermodynamic efficiencies being 32 and 33 per cent respectively.—*The Engineer* (London).

Personnel of 1922 Standards Committee

THE designation of the Standards Committee personnel for this year has been completed, the Council having taken action considerably earlier than in previous years. The prompt formation of the 1922 Divisions will enable them to begin active work soon.

The Standards Committee for 1922 will be constituted of 27 Divisions. It is believed that these will form in the main a permanent group some one or more of which can be assigned practically any subject that the Council may approve for consideration in connection with standardization. Some of the Divisions will, of course, be more active than others at certain times. The total number of members of the committee will be about 20 per cent greater than that of last year. In reorganizing several of the Divisions an effort has been made to provide added representation of the "user" class of appointees to balance more nearly the "producer" class.

STANDARDS COMMITTEE

E. A. Johnston, *Chairman*
W. G. Wall, *Vice-Chairman*
C. M. Manly, *Vice-Chairman*

AERONAUTIC DIVISION

H. M. Crane, *Chairman*	Consulting Engineer
G. J. Mead, *Vice-Chairman*	Wright Aeronautical Corporation
V. E. Clark	General Motors Research Corporation
W. L. Gilmore	Curtis Engineering Co.
L. M. Griffith	National Advisory Committee for Aeronautics
G. E. A. Hallett	Air Service
J. L. Harkness	L. W. F. Engineering Co.
J. C. Hunsaker	Navy Department
B. G. Leighton	Navy Department
L. B. Lent	Aerial Transportation Corporation
G. C. Loening	Loening Aeronautical Engineering Corporation
Glenn L. Martin	Glenn L. Martin Co.
W. H. Phipps	Ordnance Engineering Corporation
H. C. Richardson	Naval Aircraft Factory
C. I. Stanton	Post Office Department
W. T. Thomas	Thomas-Morse Aircraft Corporation
R. H. Upson	Gardner-Moffat Co.
P. W. Wittemann	Wittemann-Lewis Aircraft Co., Inc.

AGRICULTURAL POWER EQUIPMENT DIVISION

John Mainland, *Chairman*	Advance-Rumely Co.
C. B. Rose, *Vice-Chairman*	Moline Engine Co.
D. L. Arnold	International Harvester Co.
J. B. Bartholomew	Avery Co.
J. H. Davis	General Motors Research Corporation
A. H. Gilbert	Rock Island Plow Co.
R. O. Hendrickson	J. I. Case Plow Works
M. B. Morgan	Cleveland Tractor Co.
A. W. Scarratt	Minneapolis Steel & Machinery Co.
O. W. Sjogren	University of Nebraska
William Turnbull	Holt Mfg. Co.
L. W. Witry	Waterloo Gas Engine Co.
G. A. Young	Purdue University

AXLE AND WHEEL DIVISION

G. W. Dunham, *Chairman*	Savage Arms Corporation
C. C. Carlton, *Vice-Chairman*	Motor Wheel Corporation
R. S. Begg	Jordan Motor Car Co.
T. V. Buckwalter	Timken Roller Bearing Co.
A. C. Burch	Clydesdale Motor Truck Co.
R. J. Burrows	Clark Equipment Co.
L. W. Close	Bock Bearing Co.
J. Coapman	Russel Motor Axle Co.
C. S. Dahlquist	Eaton Axle Co.
F. S. Denneen	Grant Motor Car Co.
F. W. Gurney	Gurney Ball Bearing Co.
F. P. Hall, Jr.	Salisbury Axle Co.
G. W. Harper	Columbia Axle Co.
G. L. Lavery	West Steel Casting Co.
A. M. Laycock	Sheldon Axle & Spring Co.
H. V. Ludwick	Budd Wheel Corporation
C. T. Myers	Consulting Engineer
A. L. Putnam	Detroit Pressed Steel Co.
H. Vanderbeek	Timken-Detroit Axle Co.

BALL AND ROLLER BEARINGS DIVISION

F. W. Gurney, *Chairman*	Gurney Ball Bearing Co.
C. M. Manly, *Vice-Chairman*	Manly & Veal
G. R. Bott	Norma Co. of America
H. E. Brunner	S. K. F. Industries, Inc.
T. V. Buckwalter	Timken Roller Bearing Co.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America
L. W. Close	Bock Bearing Co.
L. A. Cummings	Standard Steel & Bearings, Inc.
G. W. Dunham	Savage Arms Corporation
R. G. Hendricks	King Motor Car Co.
F. G. Hughes	New Departure Mfg. Co.
G. L. Miller	Gilliam Mfg. Co.
A. J. Scaife	White Motor Co.
R. G. Schaffner	Bower Roller Bearing Co.
W. R. Strickland	Consulting Engineer
R. E. Wells	Hyatt Roller Bearing Co.

Roller Bearings Subdivision

C. M. Manly, *Chairman*	Manly & Veal
G. R. Bott	Norma Co. of America
L. W. Close	Bock Bearing Co.
G. W. Dunham	Savage Arms Corporation
C. T. Hagenlocher	Wright Roller Bearing Co.
L. R. Heim	Ball & Roller Bearing Co.
R. G. Hendricks	King Motor Car Co.
G. L. Miller	Gilliam Mfg. Co.
H. J. Porter	Timken Roller Bearing Co.
R. G. Schaffner	Bower Roller Bearing Co.
C. W. Spicer	Spicer Mfg. Corporation

CHAIN DIVISION

W. F. Cole, *Chairman*	Baldwin Chain & Mfg. Co.
H. S. Pierce, *Vice-Chairman*	Link-Belt Co.
D. B. Baker	International Harvester Co.
W. J. Belcher	Whitney Mfg. Co.
E. S. Corcoran	Kelly-Springfield Motor Truck Co.
H. F. L. Funke	H. F. L. Funke Co., Inc.
M. C. Horine	International Motor Co.
J. C. Howe	American High Speed Chain Co.
L. M. Wainwright	Diamond Chain & Mfg. Co.

ELECTRIC VEHICLE DIVISION

E. L. Clark, *Chairman*	Commercial Truck Co.
Karl Probst, *Vice-Chairman*	Milburn Wagon Co.
G. L. Bixby	Detroit Electric Car Co.

J. G. Carrol	Walker Vehicle Co.
H. M. Pierce	Ward Motor Vehicle Co.
F. E. Queeney	Lansden Co., Inc.

ELECTRICAL EQUIPMENT DIVISION

F. W. Andrew, *Chairman*	Eisemann Magneto Corporation
T. L. Lee, *Vice-Chairman*	North East Electric Co.
Azel Ames	Kerite Insulated Wire & Cable Co.
G. S. Cawthorne	Master Trucks, Inc.
W. A. Chryst	Dayton Engineering Laboratories Co.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Corporation
W. S. Haggott	Packard Electric Co.
C. H. Kindl	Westinghouse Electric & Mfg. Co.
F. C. Kroeger	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
A. D. T. Libby	Splitdorf Electrical Co.
Charles Marcus	Bijur Motor Appliance Co.
Ernest Wooler	Cleveland Automobile Co.

ENGINE DIVISION

J. B. Fisher, *Chairman*	Waukesha Motor Co.
R. J. Broege, *Vice-Chairman*	Buda Co.
P. J. Dasey	Midwest Engine Co.
S. F. Evelyn	Continental Motors Corporation
J. A. Kraus	Garford Motor Truck Co.
H. B. Massey	Holmes Automobile Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Louis Schwitzer	Automotive Parts Co.
M. J. Steele	Packard Motor Car Co.

FRAMES DIVISION

E. V. Rippingille, *Chairman*	Watson Stabilator Co.
L. J. Fralick, *Vice-Chairman*	Hydraulic Pressed Steel Co.
C. C. Bowman	Standard Motor Truck Co.
O. B. Harmon	Parish & Bingham Co.
E. L. Larson	Locomobile Co.
W. A. McKinley	Detroit Pressed Steel Co.

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corporation
W. C. Peterson, *Vice-Chairman*	Atlas Crucible Steel Co.
R. M. Bird	Bethlehem Steel Co.
H. T. Chandler	C. H. Wills & Co.
A. L. Colby	American Society for Testing Materials
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
A. P. Eves	International Harvester Co.
E. L. French	Crucible Steel Co. of America
H. L. Greene	Willys-Overland Co.
C. G. Heilman	General Motors Corporation
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Ordnance Department
A. H. Miller	Midvale Steel & Ordnance Co.
C. S. Moody	Minneapolis Steel & Machinery Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
M. P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carnegie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
H. J. Stagg	Halcomb Steel Co.
J. M. Watson	Hupp Motor Car Corporation
J. H. G. Williams	Billings & Spencer

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

E. B. Newell, *Chairman*	Westinghouse Electric & Mfg. Co.
F. C. Barton	General Electric Co.
L. F. Burger	International Harvester Co.
G. M. Gardner	Globe Electric Co.
Bryan T. Hawley	Holt Power Light Co.
L. S. Keilholtz	Delco-Light Co.
C. H. Parker	Lalley Light Corporation
C. E. Reddig	Western Electric Co.
F. L. Tubbs	Alamo Farm Light Co.
Samuel Wilbur	Sunbeam Electric Mfg. Co.

LIGHTING DIVISION

W. A. McKay, *Chairman*	Westinghouse Lamp Co.
C. A. Michel, *Vice-Chairman*	Guide Motor Lamp Mfg. Co.
J. T. Caldwell	General Electric Co.
C. E. Godley	Edmunds & Jones Corporation
C. A. B. Halvorson, Jr.	General Electric Co.
L. C. Porter	Edison Lamp Works
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Corcoran-Victor Co.
C. H. Sharp	Electrical Testing Laboratories
J. C. Stearns	Culver-Stearns Mfg. Co.
T. I. Walker	General Electric Co.
W. W. Wood	Miniature Incandescent Lamp Corporation
Ernest Wooler	Cleveland Automobile Co.

LUBRICANTS DIVISION

H. C. Mougey, *Chairman*	General Motors Research Corporation
W. E. Jominy, *Vice-Chairman*	Studebaker Corporation of America
Sydney Bevin	Tidewater Oil Sales Co.
P. J. Dasey	Midwest Engine Co.
A. P. Eves	International Harvester Co.
W. H. Herschel	Bureau of Standards
W. E. Perdew	Union Petroleum Co.
H. G. Smith	Atlantic Refining Co.
J. W. Stack	Standard Oil Co.

MOTORBOAT DIVISION

Joseph VanBlerck, *Chairman*	Wellman-Seaver-Morgan Co.
H. H. Brautigam, *Vice-Chairman*	Bridgeport Motor Co.
Irwin Chase	Elco Works
G. F. Crouch	Webbs' Academy and Home for Shipbuilders
G. C. Davison	New London Ship & Engine Co.
W. J. Deed	*Motorship*
Kirk Dyer	Frisbie Motors Co.
Q. B. Newmann	Coast Guard Service
Leonard Ochtman	Wellman-Seaver-Morgan Co.
F. B. Sexton	Sexton Motor Co.

MOTORCYCLE DIVISION

C. B. Franklin, *Chairman*	Hendee Mfg. Co.
F. W. Schwinn, *Vice-Chairman*	Excelsior Motor Mfg. & Supply Co.
W. S. Harley	Harley-Davidson Motor Co.
A. W. Herrington	Quartermaster Corps

NOMENCLATURE DIVISION

H. L. Pope, *Chairman*	Wright Aeronautical Corporation
W. P. Kennedy, *Vice-Chairman*	Consulting Engineer
W. F. Borgerd	International Harvester Co.

W. J. Brandon	Avery Co.
W. S. Brouton	Hendee Mfg. Co.
H. R. Cobleigh	National Automobile Chamber of Commerce
G. F. Crouch	Webb's Academy and Home for Shipbuilders
A. B. Cumner	Autocar Co.
L. S. Keilholtz	Delco-Light Co.
V. E. McMullen	Hercules Gas Engine Co.
W. T. Thomas	Thomas-Morse Aircraft Corporation
William Turnbull	Holt Mfg. Co.
J. G. Vincent	Manufacturers' Aircraft Association

NON-FERROUS METAL DIVISION

Charles Pack, *Chairman*	Doehler Die-Casting Co.
W. B. Price, *Vice-Chairman*	Scovill Mfg. Co.
W. H. Bassett	American Brass Co.
A. G. Carman	Franklin Die-Casting Corporation
D. L. Colwell	Stewart Mfg. Co.
G. K. Elliott	Lunkenheimer Co.
J. R. Freeman, Jr.	Bureau of Standards
E. S. Fretz	Light Mfg. & Foundry Co.
A. J. Hall	General Motors Corporation
Zay Jeffries	Aluminum Manufactures, Inc.
H. C. Mougey	General Motors Research Corporation
G. C. Ranhauser	Denby Motor Truck Co.
J. F. Thompson	International Nickel Co.
W. R. Webster	Bridgeport Brass Co.

PARTS AND FITTINGS DIVISION

F. G. Whittington, *Chairman*	Stewart-Warner Speedometer Co.
W. C. Keys, *Vice-Chairman*	Eaton Axle Co.
Clarence Carson	Dodge Bros.
E. R. Douglas	Cincinnati Ball Crank Co.
H. B. Garman	Steel Products Co.
H. S. Jandus	C. G. Spring Co.
F. W. Slack	Peerless Motor Car Co.
C. W. Spicer	Spicer Mfg. Corporation
Alex. Taub	General Motors Corporation

PASSENGER CAR DIVISION

R. S. Begg, *Chairman*	Jordan Motor Car Co.
L. A. Chaminade, *Vice-Chairman*	Studebaker Corporation of America
A. M. Dean	Templar Motors Corporation
A. W. Frehse	Standard Steel Car Co.
Maurice Olley	Rolls-Royce of America, Inc.
L. M. Stellmann	H. H. Franklin Mfg. Co.
J. H. Tuttle	Westcott Motor Car Co.

PASSENGER-CAR BODY DIVISION

G. E. Goddard, *Chairman*	Dodge Bros.
A. J. Neerken, *Vice-Chairman*	Hupp Motor Car Corporation
E. G. Budd	E. G. Budd Mfg. Co.
J. S. Burdick	Buffalo Body Corporation
F. C. Chapman	Brewster & Co.
O. H. Clark	Willys Corporation
A. E. Garrels	Studebaker Corporation of America
E. W. Goodwin	Consulting Engineer
G. W. Kerr	Rolls-Royce of America, Inc.
G. J. Mercer	Consulting Engineer
H. C. Nelson	Mullins Body Corporation

RADIATOR DIVISION

J. D. Harris, *Chairman*	McCord Mfg. Co., Inc.
C. S. Sage, *Vice-Chairman*	Sage Radiator Co., Inc.
D. L. Britton	Templar Motors Corporation
H. A. Higgins	Long Mfg. Co.
H. B. Knap	Packard Motor Car Co.
Charles Oppe	G. & O. Mfg. Co.
C. T. Perkins	Modine Mfg. Co.
G. H. Pettit	Atterbury Motor Car Co.
K. F. Walker	Fedders Mfg. Co.
J. A. White	Harrison Radiator Co.
J. G. Zummach	Zummach Engineering Service

SCREW THREADS DIVISION

E. H. Ehrmann, *Chairman*	Chicago Screw Co.
O. B. Zimmerman, *Vice-Chairman*	International Harvester Co.
Earle Buckingham	Niles-Bement-Pond Co.
E. Burdsall	Russell, Burdsall & Ward Bolt & Nut Co.
Luther Burlingame	Brown & Sharpe Mfg. Co.
G. S. Case	Lamson & Sessions Co.
W. R. Mitchell	National Acme Mfg. Co.
Alex. Taub	General Motors Corporation

SPRINGS DIVISION

S. P. Hess, *Chairman*	Detroit Steel Products Co.
H. R. McMahon, *Vice-Chairman*	Standard Steel Spring Co.
R. S. Begg	Jordan Motor Car Co.
E. S. Corcoran	Kelly-Springfield Motor Truck Co.
H. E. Figgie	Perfection Spring Co.
W. M. Newkirk	William & Harvey Rowland, Inc.
Gustof Peterson	Electric Alloy Steel Co.
E. V. Rippingille	Watson Stabilator Co.
F. A. Whitten	General Motors Truck Co.

STATIONARY ENGINE DIVISION

T. C. Menges, *Chairman*	Associated Manufacturers Co.
L. F. Burger, *Vice-Chairman*	International Harvester Co.
H. N. Edens	John Lauson Mfg. Co.
H. G. Holmes	Novo Engine Co.
V. E. McMullen	Hercules Gas Engine Co.
I. J. Nelson	Nelson Bros.
O. A. Powell	Cushman Motor Works
L. W. Witry	Waterloo Gasoline Engine Co.

STORAGE BATTERY DIVISION

W. E. Holland, *Chairman*	Philadelphia Storage Battery Co.
I. M. Noble, *Vice-Chairman*	Consulting Engineer
G. L. Bixby	Detroit Electric Car Co
R. N. Chamberlain	Gould Storage Battery Co.
E. L. Clark	Commercial Truck Co.
Bruce Ford	Electric Storage Battery Co.
C. T. Klug	Willard Storage Battery Co.
R. C. Mitchell	Edison Storage Battery Co.
W. G. Wall	National Motor Car & Vehicle Co.

TRANSMISSION DIVISION

A. C. Bryan, *Chairman*	Durston Gear Corporation
L. C. Fuller, *Vice-Chairman*	Fuller & Sons Mfg. Co.
A. W. Copland	Detroit Gear & Machine Co.
A. M. Dean	Templar Motors Corporation
J. B. Foote	Foote Bros. Gear & Machine Co.
D. E. Gamble	Borg & Beck Co.
A. A. Gloetzner	Covert Gear Co., Inc.
C. O. Guernsey	Service Motor Truck Co.
Joseph Jandesek	Republic Motor Truck Co.
W. C. Lipe	Brown-Lipe Gear Co.

C. E. Swenson	Mechanics Machine Co.
S. O. White	Warner Gear Co.

TRUCK DIVISION

F. A. Whitten, *Chairman*	General Motors Truck Co.
A. J. Scaife, *Vice-Chairman*	White Motor Co.
A. K. Brumbaugh	Autocar Co.
G. S. Cawthorne	Master Trucks, Inc.
J. R. Coleman	Selden Truck Corporation
F. W. Davis	Pierce-Arrow Motor Car Co.
H. E. Derr	International Harvester Co.
C. O. Guernsey	Service Motor Truck Co.
A. W. Herrington	Quartermaster Corps
M. C. Horine	International Motor Co.
H. B. Knap	Packard Motor Car Co.
C. B. Veal	Manly & Veal

LAW OF SUPPLY AND DEMAND

As the years go by and a better understanding is had of the actual workings of economic forces, more and more industries are realizing the necessity of studying the relation of supply to demand for their own products. Consequently they organize statistical bureaus to gather this information as to past years so that the experience of the past will be as much a gage as possible for the future and also for the present demand so as to know the flow and the relative levels in the various tanks. It is true that some of these organizations still seem to have the fallacious idea that somehow they can, by concerted action, regulate the flow. Society is benefited by close regulation of supply to demand, by not having plants built that are actually unnecessary and by using the capital that would be thus wasted in providing facilities for producing other goods. But no organization can deliberately regulate that flow any more than any socialist bureaucrat sitting in a Government office can do it.

Society must have a free market, one in which every buyer has access to every seller, and vice versa. The freer the market is, the better will competition take care of regulation. Perfectly free competition involves intelligent competition. If every company were fully informed as to costs of production in its own line, and if every buyer were equally well informed, then prices would be proper for both sellers and buyers. The buyer would expect to pay enough for his goods to cover their costs and the seller's fair profit; and the seller would not expect to get more profit than the buyer ought to pay him to produce the goods under given circumstances. As it is now, the difficulty lies in not enough information being available to either consumers or sellers to enable them to gage the market and to adjust their respective bid and asked prices to actual conditions.

Some firms set their prices in flush times on a basis of low costs at maximum capacity of their plants, and a small unit profit at that rate of production. The fact is that due to the waves, long-time costs actually rest on a basis of considerably less production year in and year out. When that kind of a seller goes out in the market he commits either business murder or business suicide by quoting prices that are lower than the economic level demands. If a price is not realized at such times that will provide a reserve to meet the next depression the company has to dip into its original capital to tide it over the gap in demand.

There is nothing in the law that does or should prevent intelligent competition. There is nothing to prevent a man from having full information as to the market that he is attempting to reach. Such information is manifestly for the benefit of society as a whole, and both buyers and sellers should have free access to it. The law does say, and properly, that there should be no artificial restraint of the market. Even if there were no law to condemn artificial restrictions and interferences with competition, such practices are unwise and uneconomic, and such restrictions always carry within themselves the seeds of their own dissolution. Those who try such restraints endeavor to work against economic law, as well as against statute law. This cannot be successful economics because it is unsound economics, and should be abandoned for that reason if for no other. Cut-throat competition is just as uneconomic, and brings its own penalty by compelling the competitor to retaliate to preserve his own existence, and the cut-throat loses more than he can possibly gain. Here again, what is perfectly good economics is strictly in accord with the Golden Rule.—E. F. Dubrul in *American Machinist*.

INDUSTRIAL CONDITIONS IN EUROPE

NDUSTRIAL affairs in England are somewhat complicated by their socialistic experiments, most of which have failed to accomplish what was expected of them. For example, the attempt to solve the problem of unemployment by payments based on idleness rather than on work is an economic failure. Not only in England and France but in Russia people are beginning to realize that the millennium is not to be brought about through governmental agencies, but rather through the orderly operation of economic laws. England, the greatest trading nation in the world, knows what competition is, knows that her future depends upon foreign trade and is preparing to meet it in her own shops and with her own ships.

France is fundamentally an agricultural country, a country of well-to-do peasants, and as such is more prosperous than we have been led to believe. Of course the manufacturing industry is at a low ebb but unemployment is not marked, and I was told that the men out of work in industry were back on the farms where they work for food and lodging so that foodstuffs are produced more cheaply and prosperity gets its fundamental start. The French know how to live cheaply and when times are good they save money.

In Germany it appeared to me that conditions were better than in any other country I visited. Not only are they not looking for any outside help such as the allied countries may expect from reparations, but they do not seem to be worrying about the reparations, and it appeared to me that they do not seem to believe they will ever be forced to pay or if at all not in any way that would inconvenience them to any great extent. Germany, of course, is a great manufacturing and industrial country and while France and England are industrially flat German industry is comparatively prosperous. With the mark at so low an exchange value they can undersell any other country, and realizing in a sense that they were defeated temporarily in their ambitions, their workmen are willing to take what they can get. Their factories are uninjured and in a high state of efficiency.

It seems to me that the European people learned from the war a lesson of real sacrifice and with the dangers that confront them recognize that they must continue to sacrifice to work back to more normal conditions.—A. C. Higgins in *American Machinist*.

Body Seating-Dimensions

By George E. Goddard[1]

Annual Meeting Paper *Illustrated with* Drawing

THE dimensions of automobile-body seats receive consideration with regard to the features that are conducive to comfort. A diagram is presented upon which the dimensions treated are indicated, and a tabulation of seat dimensions of 12 representative cars is included.

Comments are made upon the factors influencing seat dimensions, as well as recommendations regarding the different desirable dimensions. The considerations are inclusive of cushion height, depth and slope, leg-room and head-room, upholstery shape and softness of trimming, foot-rest and other control-element locations, factors influencing entrance and egress provisions, seat widths and advisable front and rear-compartment heights.

The author recommends the standardization of a range of locations for the different control elements.

THE subject of body seating-dimensions is liable to variations of opinion and, undoubtedly, this is legitimate. Naturally, we do not all agree upon what constitutes the most comfortable chair; if we did, we might all be buying the same chair. Therefore, body seating-dimensions are not a subject for standardization; they can, however, be given very serious consideration and the intention of this paper is to elucidate certain necessary features conducive to comfort.

Cushion Height, Depth and Slope

The mode of women's dress is of prime importance. It is very fortunate for the body designer that women are wearing shorter skirts at present, and that they girdle themselves with a support of minimum proportions, particularly as to vertical dimensions. Seat-cushion heights are now, or can be made, as low as is necessary to secure the assumption of a comfortable sitting position, or to arise from that to a standing position; in other words, it is necessary that the passenger be able to sit down and to arise easily and naturally.

I will call the space in front of the seat "leg-room." Naturally, this space must be increased to conform to the lowered sitting position. It is here that one of the greatest variations in seating dimensions occurs. When this leg-room is restricted, the final position must be made comfortable by incorporating the proper slope in the cushion and the corresponding slant in the seat-back. It has been stated that the semi-reclining position attained in the deck chair, so common on ocean liners, is the ideal. This may be entirely correct, but I doubt if it can be duplicated in conservative motor-body design. However, it can and should be approached in the passenger car, because it contributes to the attainment of a horizontal line of vision that is more nearly equal in elevation to that of an individual who has assumed a standing position. The more nearly the eye-line height of the passengers is brought to that of a person who is walking, the more they will be at ease, if for no other reason than that man's work is carried out mainly from this viewpoint.

[1] M.S.A.E.—Assistant chief engineer, Dodge Bros., Detroit.

The depth of the cushion, from front to back, is affected by both the height and the leg-room. If the latter is not restricted, the slope can be made slight and the depth greater. If it becomes necessary to draw the legs back, the knees are raised and the body must be supported by the cushion at a greater slope. In coming back, the calves of the legs would interfere with the front of the cushion and it must be made more shallow. The seat-back must be slanted more, the back springs slightly stiffened and the "foot-rest position" located within comfortable reach. These seem to be the elements to be given major consideration. I recommend 12 in. at the front of the cushion as a good compromise position, with a minimum depth of 17 in. on a 2-in. slope and a minimum back-height of 17 in.; also, for the rear seat, a 14-in. height at the front of the cushion, with a minimum depth of 19 in. on a 2-in. slope and a minimum back-height of 19 in. These dimensions are, of course, dependent upon the pedal position from the front edge to the cushion of 19 in. and a foot-rail position of 18 in., measured correspondingly, and reference is made to Fig. 1 and to the last line of figures in the tabulation. It has been found preferable to have rear-seat passengers ride slightly higher than those in the front seat, to secure clearer forward vision. The 2 in. recommended, when combined with the slope of the chassis, which should be from 1 to 2 in. with a full complement of passengers, is sufficient under average conditions.

Upholstery Shape

To deviate for the moment from the actual dimensions of seats, the correct shaping of the seat, the upholstery contour, is of far greater importance than either its proportions or softness. The dimensions may be such as to provide a well-proportioned seat, and yet it may be a very uncomfortable seat for even a short ride. The angular relation of the cushion and the back upholstery must be right. This relation will vary somewhat with the height of the cushion and the foot-rest position, but the angle will average about 95 deg. The cushion should have an approximately flat slope, but the back upholstery shape must have a properly curved contour. This contour naturally does not vary to a great extent as to characteristic shape regardless of the height, depth or slope of the cushion, or the height of the back upholstery itself. It is obvious that the occupant's back must be supported, but proper support is lacking in a great many seat-backs. If, when seated, one's back can "cave out," there are very few who can ride 10 blocks in comfort; but, if one's back is properly supported against curvature, one could drive or ride for a four-day 1000-mile trip and feel sufficiently fit at the finish to turn around and do it again. Strange to say, the average trimmer fails to produce this desirable shape without considerable coercion, and particularly a properly graduated resistance to prevent curvature. The back upholstery must be shaped so as to have a prominence of the proper resistance, and be at the proper height from the cushion to fit the small of one's back. It must, nevertheless, taper off toward the top to

provide ample shoulder-freedom. This is particularly important for the person at the wheel. The resistance at this point can be fairly stiff and yet be comfortable. In fact that supposed 1000-mile ride depends upon making it stiff. There should be very little movement of one's back at this point; the movement should occur at the hips. The driver needs this resisting prominence in particular, to enable him to attain a confident and comfortable operation of the clutch and brake-pedals, if for no other reason. Without attempting to give details of the layout of this shape, I would say that the gradation of the springs of four-row backs can be made so that the bottom row has No. 13, the main row No. 12, the third row No. 13 and the top row No. 14 springs. However, this can all be laid out on paper. From this, drawings and specifications of the back-spring construction, as well as of the cushion, the back and the final inspection templates, can be determined.

Softness of trimming is controlled to a great extent by the trimmer but, if the final contour of the combined cushion and back is obtained, together with a properly related foot-rest position, the slight variation occurring as to softness is inconsiderable. If it is to be featured, softness should be obtained in the spring construction almost entirely, especially in the straight-pleated type. The cushion top should be firm, to enable it to endure for proper length of time.

Position of Foot-Rest, Steering-Wheel and Controls

The term "foot-rest position" has been used as applying to the brake and clutch-pedals and to the foot-rail. It applies also, and perhaps more particularly, to the accelerator-pedal. It is obvious, then, that the last-named should be located at a slightly greater distance than the other pedals for, when operating clutch or brake, sufficient freedom of movement between the thigh and the cushion must be allowed for, when determining the slope of the cushion. Since the accelerator-pedal has less effective travel, it must be positioned to take up practically all of this freedom in order that the thigh be comfortably supported along the entire length of the cushion slope. An accelerator-pedal toe-rest cannot accomplish this; it can merely produce ankle comfort. The height *H* of the pedal-pads from the floor, as shown in Fig. 1, is a dimension that deserves much study. How the improper position of some of the existent pedal-pads has been arrived at, is a mystery. I suggest that the Society formulate a diagram of control dimensions locating pedal-pads, lever-grips, the handles and knobs on the instrument-board, and the like, from the center of the bottom of the steering-wheel rim. The height of the foot-rail *L* should be such that the front of a man's shoe heel can be braced underneath the lower edge. This height will then be such that the ball of a woman's foot will rest usually on the center of the rail. The slope of the toe-board should be approximately at right angles to the calf of the leg, located so that the thigh rests along the entire length of the cushion slope and within comfortable reach. The sitting position should be determined properly, regardless of the control.

It has been shown how the pedals should be located in relation to the seat. The steering-wheel and hand-levers should be treated in the same manner. I recommend a minimum distance below the wheel of 8 in. and a space of 15 in. to the back upholstery, as indicated by the letters *I* and *J* in Fig. 1.

The arm-rest position also must be given due consideration. On open cars, the height of the body side properly should be determined from this viewpoint, unless the seat width is sufficient to provide a built-in arm-rest. A minimum of 9 in. is recommended.

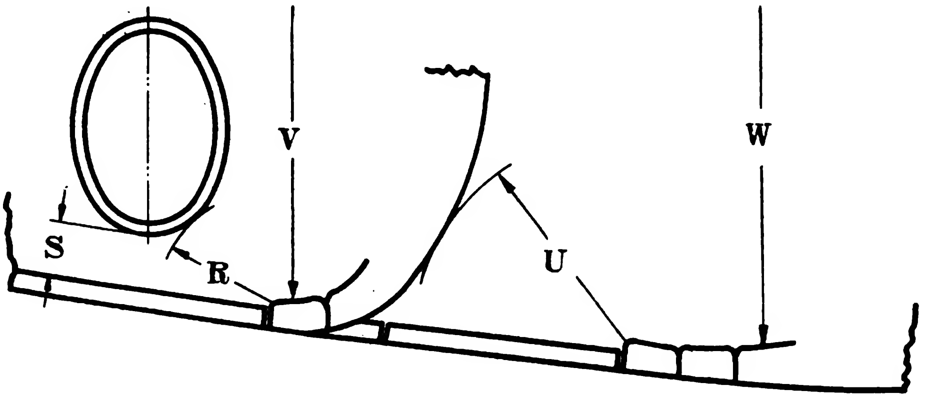
Head-Room

Head-room is a fairly well-established dimension. Where the door width is ample and the running-board is positioned properly, the entering and leaving of the car is accomplished without assuming even a stooping position. The head-room at the front seat can be less than that at the rear, being between axles. The greater range of chassis spring-action at the rear makes it advisable to provide slightly more head-room over the rear cushion. The minimum to be recommended for the front seat is 37 in. and, for the rear, 38 in., measured vertically at a point 12 in. back of the front edge of the cushion and 8 in. from the side of the body, as indicated by the letters *M* and *N* in Fig. 1. Although but 36 in. has been provided in some bodies, this dimension generally is accompanied by an unusually soft cushion.

The entering and leaving of the car has been mentioned in connection with door widths and the like, but the actual clearance between the parts of the structure is the true viewpoint to assume for such considerations. For instance, the distance between the corner of the front seat, or a curved partition, to the rear-door hinge-pillar must provide a comfortable "hip clearance." A minimum of 17 in. is recommended, as indicated by the letter *U* in Fig. 1. This dimension will provide sufficient shoulder-clearance, although more room than this is desirable, particularly if the door is hinged on the front pillar. For entrance to the front seat, "shoulder-clearance" should be considered in connection with the slanted windshield or body front. When using the wheel side for entering or leaving the car, ample leg or "body-clearance" should be provided between the wheel and the seat-arm or front-door rear-pillar. A minimum of 9 in. is recommended for open bodies, as indicated by the letter *R* in Fig. 1. This should be slightly greater on closed bodies and in both open and closed types, where the front door is hung on the rear pillar. Of course, where the body space is limited, this can be accomplished with the aid of a sliding or tilting steering-wheel.

Seat Width

The width of seats varies from 37 to 42 in. for front seats, as shown in the tabulation in Fig. 1. This dimension is determined more by body design than from the standpoint of proper space for two passengers. While 16 in. of cushion space is sufficient for the average person, a minimum shoulder-space of 18 in. should be allowed for passengers. For the driver, I prefer to provide a 21-in. shoulder-space to allow ample freedom of arm movement. A front-seat width of 40 in. will satisfy these requirements and, with the steering-column 10 in. from the center-line of the car, the driver will be able to sit directly behind the wheel. It is true that many bodies can be found that are narrower at this point, but too sudden a contraction cramps the left-arm movement of the driver. The inside measurement of the body, taken across the center of the steering-wheel, should not be less than 45 in. The space *S* will then be but 4 in. when a 17-in. wheel is provided on a column in the location already stated, as shown in Fig. 1. I have driven cars that it hardly would have been safe to have driven in congested traffic or in unusually bad going if the front window had not been lowered or the door curtain left off. Cramping at this point should not be encouraged, at least. The hand-clearance between the wheel and the windshield should not be less than 3 in., although this



DIMENSIONS FOR "AVERAGE" DO NOT INCLUDE No. 12.

O -MINIMUM PRACTICAL } EACH DIMENSION IN THESE TWO LINES IS GIVEN AS AN INDIVIDUAL
* -MINIMUM RECOMMENDED } MINIMUM. COMBINATIONS OF SOME DIMENSIONS NOT FEASIBLE.

Fig. 1—Dimensions That Influence the Design and Location of Seats

depends somewhat on the rake of the steering-column of course. The width of rear seats, as shown in the figures for 12 cars tabulated in Fig. 1, averages 45 in. for three passengers. It is preferable to provide, as nearly as is possible, a 16-in. cushion-space for each passenger.

Depth of Front and Rear Compartments

The distance between the front cushion and the dash, 30 in., usually is ample and does not vary to a great extent, as is shown in the tabulation of the dimensions of 12 different bodies in Fig. 1. The space provided between the rear cushion and the back of the front seat is determined by the use to which it is to be put. With the rear cushion in the compromise position recommended in the first part of this paper, the minimum distance should not be less than 21 in. If ample space for wearing apparel carried on the robe-rail or room for a traveling-case is desired, it will be necessary to increase this dimension, but 24 in. gives a comfortable compartment.

Knee-room to the front and rear of folding-seats in seven-passenger bodies or bodies having staggered seats should not be less than 26 in., measured from the back upholstery to the part of the structure in front. Therefore, allowing 1 in. for the thickness of the folding-seat back, the distance from the back upholstery of the stationary seat to the structure in front should not be less than 53 in.

Standardization of Control Dimensions

In conclusion, I wish to make another plea for the standardization of a range of locations for the control elements as outlined, and also to suggest that a manikin be developed to conform to the average dimensions of the human body, so that it can be used as a standard from which to work. If this accomplished nothing more than the discouraging of such proportions as are found in some of the bodies shown at one of the recent foreign shows, it would be well worthwhile.

DEOXIDATION OF STEEL

A THOROUGH study of the theory and practice of oxidation of steel was initiated by the National Research Council during the war. This important work has been continued under the direction of J. R. Cain, chairman of the Committee on Substitute Deoxidizers. This committee has issued a progress report, which will be followed by a more extended technical report, and extracts from the former follow.

One of the most difficult operations of steel metallurgy, called deoxidation, is that of removing from the molten metal before casting into ingots certain gaseous and solid foreign substances, known to the metallurgist as inclusions, that unavoidably enter the metal during the melting processes. Such foreign substances are present in varying amount and kind, no matter whether the steel is made in the Bessemer converter, the open-hearth furnace, in crucibles or in electric furnaces. The substantial removal of these substances or of their effects is fundamental and vital, because if ingots were cast from steel containing such inclusions they would be too brittle for the subsequent operations of rolling or forging, or would contain so great a proportion of blowholes as to be useless for most purposes.

Silicon, aluminum, manganese and titanium are the chemical elements that have been most used. These are generally employed in the form of their alloys with iron, except in the case of aluminum. Manganese is the most important of all the deoxidizing elements. In the present state of the art it is impossible to make steel that can be forged successfully or rolled without the use of manganese. It is the only one of the four elements mentioned that removes the fatal brittleness during hot-working that results from the presence of small amounts of sulphur that all steels contain. Without recourse to manganese the steel metallurgist would be forced to make steel almost free from sulphur to get a product useful in the arts; something well-nigh impossible with present-day high-sulphur fuels and steel scrap.

The committee has confined its experiments to 73 combinations of deoxidizing elements that exhibit characteristics worthy of further consideration. Methods had to be devised for making up the various mixtures and testing them under experimental conditions with a view to developing data and methods of procedure that could be subsequently applied to actual production conditions.

In devising methods for testing the efficiency of the deoxidizers a great amount of pioneer work has been necessary, for almost nothing had been done by others. The aim has been to study those functions of the deoxidizer that are deemed of most immediate interest to the steel manufacturers: (*a*) the greatest possible yield of sound ingots free from blowholes and with the minimum amount of shrinkage cavities; (*b*) the making of steel having satisfactory rolling and forging properties; (*c*) the production of metal free from iron oxide, slag or other solid inclusions; and (*d*) the fabrication of steel with the maximum freedom from dissolved gases.

Although actual tests of the alloys have only begun, there have been indications of very interesting results. For instance, some alloys have shown marked superiority in preventing segregation; others have given promise of replacing manganese to some extent in eliminating sulphur red-shortness. There has been opened up the possibility of refining the grain structure of steels by using special deoxidizers, and in many cases there is a great superiority in respect to the reduction of ingot loss from discards due to shrinkage cavities. As yet these are regarded only as indications of what can be expected, and for this reason no details as to particular alloys are justified at this time. However, it is hoped that the support for this work may soon make possible the full realization of these possibilities by those industries that can expect to be benefited.

The limited amount of work already done in testing the alloys has demonstrated that it will be possible not only to use less manganese alloy, whether of high or low percentage, but also to produce more or better steel by the use of the new alloys.

ENGINEERS IN PUBLIC DISCUSSION

FEW, if any, of our engineering institutions lay sufficient stress upon the importance of an engineer's ability to write correctly and to speak the English or any other language or to appear at ease before an audience. In consequence, thousands of otherwise capable engineers feel handicapped and make a bad impression when participating in public discussions. It is not sufficient that instruction along this line be given in the preparatory schools only, but should be accorded a very definite place, and its importance impressed upon the student throughout his college course.—F. D. Nash in *Engineering News-Record.*

Standards Committee Meeting

THE Standards Committee Meeting convened at 10:15 a. m., Tuesday, Jan. 10. Chairman B. B. Bachman spoke briefly on the procedure to be followed in the sessions in passing on the reports of the several Divisions.

The complete reports of the Divisions were published on pages 383 to 435 inclusive of the December 1921 issue of THE JOURNAL, and are those referred to hereinafter in connection with modifications that have been made in them, owing to typographical errors, changes directed by the Divisions after the reports were printed, or amendments at the Standards Committee, the Society or the Council meetings. The reports that were approved at these meetings are to be submitted to the Members of the Society for approval by letter ballot. This mail vote will be recorded at the offices of the Society on Saturday, March 11, that is 60 days after the Standards Committee meeting. The letter-ballot forms will be sent to the Members of the Society separately and should be returned on or before March 11 to be recorded.

AERONAUTIC DIVISION

(1) *Tachometer Drive*

[This report as printed on page 383 of the December JOURNAL was duly approved.]

THE DISCUSSION

H. M. CRANE:—The Aeronautic Division has again marked time as it was foreseen it would, partly due because the work done during the war rather outran the standardizing possibilities in the industry. This is exemplified in the case of the report presented today for revision of the standard for the Tachometer Drive. The tachometer drive was practically standardized in the original design without any notable amount of actual experience and proved to be too weak a construction for some of the large twin-engined machines in which long drive-shafts are required. In addition to this report of the Aeronautic Division, however, it should be noted that the Aeronautic Division is taking advantage of a large number of the Society's other standards. For instance, the report of the Iron and Steel Division applies practically as much to aircraft engine and plane standardization as it does to the construction of passenger cars.

BALL AND ROLLER BEARINGS DIVISION

(2) *Annular Ball Bearings*

[This report as printed on pages 383 and 384 was duly approved.]

THE DISCUSSION

F. W. GURNEY:—Last summer a complaint was made by one of the leading transmission manufacturers that the bore tolerances of ball bearings were not close enough. Aside from the automotive industries, especially among machine-tool builders, this complaint is much more insistent. After much consideration the Division finally agreed to revise the tolerances, which were previously from plus 0.002 in. to various minus values. The Division found that it is general practice to manufacture to plus zero, all the tolerances being minus.

CHAIN DIVISION

(3) *Roller-Chain Sprocket-Cutters*

[This report as printed on page 384 was duly approved.]

THE DISCUSSION

H. S. PIERCE:—The details of the cutters described in this report will be worked out and presented to the Society later on. At the Division meetings the general principles on which they will be designed were decided upon; and, as the standard tooth-form has been determined, it practically fixes the details. The use of straddle cutters is advantageous to manufacturers who do not produce a large number of any one size of wheel but have a number of miscellaneous sizes to make.

(4) *Roller Chains*

[This report as printed on pages 384 and 385 was duly approved.]

THE DISCUSSION

MR. PIERCE:—The formula and the table given in this report are recommended practice for the minimum breaking-strength of chains, and were developed by reason of a peculiar situation that has gradually developed in the industry. The only data that have been published generally on roller-chain strength refer to the ultimate strength and the general proportions. The ultimate strengths were, of course, for static test. They were also published generally as average strengths, which they actually are, but in cases of test, to increase the minimum ultimate-strength to be sure of passing the specification, certain elements in manufacture were showing a trend in the wrong direction. The ultimate strength of a roller chain can be increased by reducing the depth of the case on the pin, and by giving the pin a heat-treatment principally for the core, and increasing the carbon-content of the core. Actually, what is desired in roller chains is a high wearing quality and a great resistance to failure in service; dynamic strength rather than static strength.

The recommended values are slightly less than those generally published on ultimate strength, so that the efforts of the manufacturers can be directed toward really making better chains than to meet a nominal specification.

F. L. MORSE:—The point I wish to raise is that it is inadvisable to specify a minimum breaking-strength for publication, as this prevents in a certain measure the constant improvement that can be effected by the use of better grades of steel. Every manufacturer should have a free hand to increase the minimum breaking-strengths by such methods. This is well recognized as a means for improving production, where various grades of materials enter, and it seems to me that when a company uses the better grades of material, it should be permitted to receive the benefit of such increased cost as is reflected in the possible minimum breaking-strength.

M. C. HORINE:—This proposal was formulated by a joint committee of the American Society of Mechanical Engineers and this Society, and it was necessary to consider the application of roller chains in a rather broader field than that of the automotive industry. The result is that chains have been considered that have no automotive application, and I think that the minimum breaking-strength figures have been affected somewhat by the requirements of the general mechanical use of chains, which are not as severe as those in automotive applications, especially in truck and tractor drives. I believe that the proposed standard minimum breaking-strengths are too low, as the automotive industry is trying to get better, stronger chains all the time.

MR. PIERCE:—The ultimate strengths can be increased but it would be as a rule at the expense of elements that are really of much more value. If a chain comes up to the minimum ultimate-strength specified in the report and actually breaks in service under the static pull, it is really too light for the work.

The wearing quality of the chain depends on the character and the depth of the case on the pin. The deeper the case is, the less the ultimate strength is. If the pin is heat-treated to develop the best wearing qualities which is the element we really need, it is not heat-treated to bring out the maximum shearing strength also. In other words, the parts need a toughening treatment to get the best results. I think that every user of roller chains wants longer life.

If the only specification published is for a static test, conservative values will result in better chains, whereas higher values would tend toward improper design and manufacture. As better grades of material are developed, the values specified can be revised. But fairly high-grade materials, all good alloy-steels, are now used where chains have to stand the maximum work.

MR. CRANE:—Are these values supposed to indicate safe running loads on the chains on the order of what is used as safe running loads on ball bearings or roller bearings, or are they strengths to show on a testing machine whether the chain is up to specification?

MR. PIERCE:—These values are for tests on a static testing machine and are higher than any safe working load.

MR. CRANE:—I think that it is very desirable to state that clearly in this recommendation because so many standards of other kinds are used by engineers that the intent of this one might be mistaken.

C. N. DAWE:—Mr. Pierce said that the deeper the case is the less the ultimate strength is. Is he basing any opinion on that?

MR. PIERCE:—The chain pins are made of lower carbon-steel and the greater the depth of case is, the lower the shearing strength is. If the pins are given a heat-treatment for the case, it does not develop the maximum strength in the core. A tough pin is desired rather than just a hard one because an extremely hard pin is likely to fail under fatigue. Although these figures refer to a static test, the service is dynamic.

E. A. JOHNSTON:—It has been my experience that very few chains fail, and that failure is not always due to the shearing of a pin. In many cases it is caused by the bushing becoming loose in the side-bar. I have tested many chains with pins made of heat-treated alloy-steel. Specifying the minimum ultimate-strength will not prevent any chain-maker from advertising or stating that his chain has a much higher strength; that is simply a standard of measure to gage by. I believe also that the safe working strength of a chain, or the load on a chain, would be preferable to the ultimate breaking-strength.

MR. PIERCE:—It has been the practice of roller-chain manufacturers to publish not a minimum ultimate-strength, but an average. The natural variation in the material they get is a little below or above that average. This probably shows a factor that is a safety margin of 10 per cent, but there has been a tendency all along to derive a specification based on the strength of the chain, whereas it was not the strength of the chain that needed improvement; it was other elements at the expense of which strengths were being kept up. It would not be possible to recommend with safety working loads of chains, because the conditions under which they operate in the automotive industry alone, in the various applications, the speeds at which they run and the character of work require entirely different considerations.

F. W. ANDREW:—It seems to me that roller-chain users and the trade generally wish all the information contained in this report and I think that it should be approved.

MR. PIERCE:—We are trying to get some satisfactory engineering data on roller-chains with regard to working loads and the various other points for recommended practice, but our study has not yet been completed. This report is a step toward completing this work.

ELECTRICAL EQUIPMENT DIVISION

(5) *Insulated Cable*

[This report as printed on page 385 was duly approved.]

(6) *Starting-Motor Flange Mountings*

[This report as printed on page 385 was duly approved.]

(7) *Flexible Steel Conduit*

[This report as printed on pages 385-387 was duly approved.]

(8) *Non-Metallic Conduit*

[This report as printed on page 387 was duly approved with the exception that the minimum radius of ½ in. for bending, given in the last column of Table 5 and in the next to the last line of paragraph (5) was changed to 3 in.]

ENGINE DIVISION

(9) *Carbureter Flanges*

[This report as printed on page 388 was duly approved.]

(10) *Engine Numbers*

[This report as printed on pages 388 and 389 was by amending action duly approved for adoption as S. A. E. Recommended Practice as an alternative to the present S. A. E. Standard on page A13 of the S. A. E. HANDBOOK.]

THE DISCUSSION

MR. CRANE:—While I can see some difficulties in the method of numbering by casting the number directly on the crankcase, I would like to ask what difficulties the Division considered insuperable in connection with such a method in a factory building its own product. It seems to me to be probably the easiest thing to do in the long run. A crankcase might have to be scrapped from time to time, but there would be a complete record of the numbers, and it would simply result in the engine number of the last car put out being higher than the total number of cars. On the other hand, in the case of an engine builder producing engines for different car-makers, the procedure might lead to argument regarding the engine numbers. The engine builder would have to use serial numbers based on his production of engines, and this might not agree with what the car maker would want.

As far as effectiveness against altering numbers is concerned, it is one system that is certainly 100 per cent safe because it is absolutely impossible for any man stealing a car to alter or reproduce the number on a crankcase without practically reproducing the whole crankcase.

J. B. FISHER:—I agree with Mr. Crane that it would be ideal to cast the numbers on the crankcase and that the numbering could be controlled readily if the car builder were making engines for himself; but it is very difficult to control the numbers when making engines for several buyers. It is the desire of the Division to recommend a numbering system that will be used universally

Correct Method of Stamping Engine Numbers

by companies making their own engines and by companies who purchase from engine builders.

Mr. Crane:—Would the Division object to having more than one system? It seems to me that the casting system has such simplicity compared to the system recommended that there is no reason why the Society should not recommend it to companies that are in a position to use it. It should be the preferred method, I think. The other should be the method where it is necessary to have a more flexible system of numbering for one reason or another than can be obtained by the cast numbers.

Mr. Fisher:—I think there would be no objection to having an optional system.

A. J. Scaife:—I would like to inquire whether the Underwriters Laboratories has approved this method and, if not, whether it is advisable to accept it as a standard. When we first considered this subject there was discussion of this method and it seemed advisable for us to recommend a method that would be approved by the Laboratories before we adopted it.

Mr. Fisher:—A set of sample plates was made up and forwarded to the Underwriters Laboratories at Chicago. It has not submitted its report to us yet.

R. S. Burnett:—Mr. Small, vice-president of the Underwriters Laboratories, has stated that this recommendation looks as promising as anything that had been brought to light so far. We are awaiting advices from the laboratories as to the result of testing this method of numbering engines.

W. S. Haggott:—I do not know that it is necessary to get the underwriters' approval on a matter of this kind. If it is a good thing, the Society could adopt it anyway.

Mr. Horine:—With reference to Mr. Crane's remarks on casting the number on the crankcase, I would say that a proposal was made some time ago for a checkerboard system, specifying digits from 0 to 9 in vertical columns and a sufficient number of columns to make up the number of digits in the number. The actual number would be shown by drilling out all digits not wanted in each row. That, it seems to me, would be utterly impossible to change, although it would not provide for error any more than the straight casting method. It would, however, make it impossible for a thief to grind down the surface of the casting and restamp a new number, which can be done where the number is merely stamped in the crankcase, as is now the practice.

Mr. Fisher:—That proposal was made at the Division meetings. The objections to it were the large amount of drilling necessary to get the number on each crankcase and that it would be possible to drill out one or more of these numbers and insert plugs of the same metal with different numbers on them. A competent mechanic could do that in a way that would be very hard to detect. We are aiming at simplicity above everything else, and trying to get an effective method that can be used with the least work and expense in the foundry and in the shop.

Chairman Bachman:—The Division has considered the question of numbering engines in such a manner that the marking cannot be altered by an unauthorized person. The desirability of such a system is self-evident. A number of ideas have been submitted; among them the ones that Mr. Crane and Mr. Horine have indicated. The Division has recommended a method that in its opinion is possible and simple, but, as has been pointed out, the benefits of adopting such a system are dependent in part at least upon its acceptance by the Underwriters Laboratories. It may be desirable for us to proceed along our own lines, standardizing what we conceive to be good, or to await the approval of other organizations before we take action. It may be possible to have two acceptable systems; one that would be used by those making their own engines and another for use under different conditions.

Mr. Burnett:—This proposal is in the form of a revision of an S. A. E. Standard that has been in The Handbook for a number of years. The present standard specifies the stamping of numbers at least ¼ in. high. That is as far as it goes.

Mr. Crane:—The proposal is for a safety system of numbering. The other was simply a system of numbering without any regard to its safety.

A. K. Brumbaugh:—Even after stamping the numbers on the rough surface of the casting and between the rough parallels, it is possible to cut out the numbers and sandblast that part of the casting so that in a very short time afterward it will have the same appearance as the original surface with the new or false numbers stamped in. Approval of this recommendation, even as a recommended practice, means a change of patterns and possibly foundry methods that would be justified only by having something that is final and acceptable to the insurance authorities.

Unacceptable Method of Stamping Engine Numbers

(11) *Fan Belts and Pulleys*

[This report as printed on pages 389 and 390 was duly approved with the exception that in Tables 6 and 7 the term "inclusive" should apply to the column of "Maximum Fan Diameters."]

THE DISCUSSION

W. L. GILMER:—Standardization of fan belts and pulleys is really necessary. At present very little has been done following such standards as have been set. The majority of the fans on automobiles are from 15 to 18 in. in diameter and of 1⅞-in. or less projected blade-width. The belt widths range from ⅝ to 1½ in. These recommendations seem to be based entirely on fan diameter and projected blade-path, while they should be based on the power requirements of the fan, the fan diameter and speed, the projected blade-path and the size of pulleys. For instance, a 1¼-in. belt with a 15-in. fan of 1⅜-in. blade-width traveling at 200 r.p.m. will require about 1/16 hp. An 18-in. fan of 1⅞-in. blade-width will take 1.8 hp at the same speed. If the speed is increased, the power required at the belt is considerably larger. Both of those fans do not require the same width of belt. It would be very much better if the pulley and belt widths were specified according to the power that is required with them.

As large pulleys as possible should be used so as to get higher belt speeds, lower initial belt-tension and greater belt contact on the pulleys. It is a mistake to crown both pulleys. In assembling an automobile it is almost impossible to get the peak of the crown on both pulleys in perfect alignment, and if the pulleys are not in alignment, they will force the belt to travel crookedly or weave, resulting in the belt binding on the flange and jumping off the pulley. The crown should be on the driving pulley only; not on the fan pulley. A crown of 1/16 in. on the fan pulley will reduce the power-transmitting capacity of the belt from 10 to 15 per cent. The crown recommended will average about 1/16 in. and in many applications will allow the belt to be considerably overloaded. The fan pulley is usually smaller than the driving pulley and consequently has less belt contact. If this belt contact is further reduced by crowning it, the belt capacity will be reduced to an extent that will be troublesome.

G. A. BARNARD:—I subscribe heartily to everything that Mr. Gilmer has said. He called attention to the fact that fan-belt and pulley requirements are based on horsepower. I think that this recommendation is a step far in advance of what has ever been done. I think it should be accepted, but there is still the need for a tremendous amount of investigation along the lines suggested by Mr. Gilmer to determine the horsepower ratings of fans and also of generators and pumps. Very few manufacturers appreciate how tremendously the horsepower requirements increase with slight increases in fan speed. Referring to Fig. 2, I suggest that the terms referring to the V-belt pulley "For power drives" and "For fan drives," be clarified. I would like to inquire why the 38-deg. angle is recommended for the V-belt on the fan drive.

MR. FISHER:—The expression "For fan drives" refers to applications in which only the fan is driven. The expression "For power drives" includes applications in which also the generator or the pump is driven off the same belt. The two angles were selected after a careful study of those in general use. It seemed to the Division that they are about the best that can be recommended. Permitting the belt to slip more readily at high speeds was one of the factors that affected the selection of these angles.

I am sorry that Mr. Schwitzer of the Automotive Parts Co. is unable to be here today, as he was Chairman of the Subdivision that investigated this subject very carefully and prepared a comprehensive report on it.

I would like to state that determining the fan horsepower by the projected width of the blades is not a very satisfactory method. We have found that a fan-blade of 2¼-in. projected width may take less horsepower than a fan of the same diameter having only 1⅞-in. projected width, because much depends upon the angle of the blades and the type of bearing in the fan. It is difficult to determine the horsepower required from the diameter of the fan and the projected width of the blade.

CHAIRMAN BACHMAN:—There is, undoubtedly, room for difference of opinion on this subject, but the probabilities are that this work will be expanded and continued.

MR. BARNARD:—I am not opposed to the approval of this recommendation. I am heartily in favor of it.

F. G. WHITTINGTON:—Was the consideration of this subject based on two, three, four, five or six-blade fans? A 20-blade fan would reduce the required horsepower to practically nothing. Most of our work has been done with the conventional four-blade fans.

MR. FISHER:—I believe this recommendation is based largely on conventional four-blade practice, but most of it will undoubtedly apply to other fans.

(12) *Mufflers*

[This report as printed on page 391 was duly approved.]

THE DISCUSSION

RALPH MURPHY:—We believe that in many cases a smaller muffler will be satisfactory. We also believe that a smaller pipe and tail-pipe would be satisfactory with a smaller muffler. We suggest a muffler 5 in. in diameter with a volume of approximately 350 cu. in. and a tail-pipe of 1¼-in. diameter.

MR. HORINE:—The standard proposed does not include the larger sizes for trucks and particularly for tractors. The motor truck and the automobile are pretty closely allied and it seems to me that this recommendation might very well be extended to include 4-in. exhaust-pipes.

There is also some difference of opinion as to whether the tail-pipe should be smaller than the exhaust-pipe. Some manufacturers make the tail-pipe larger than the exhaust-pipe on the principle of slowing-down the flow of the exhaust gas instead of speeding it up. It would not seem to be any violation of the principles of standardization to provide some option on the tail-pipe size, so that a manufacturer could use a larger tail-pipe, if he wished to.

If it is not desired to extend the sizes of exhaust-pipe to include heavy trucks, the recommendation should be specified as a passenger-car and not a motor-truck standard.

MR. FISHER: The Division felt that the 3-in. diameter exhaust-pipe is larger than most of those in general passenger-car and truck practice.

MR. HORINE:—We use a 4-in. size.

MR. FISHER:—Your company is one of the few that uses so large a size. It was felt that anyone using a pipe that large would naturally install a special muffler in connection with it. For instance, the muffler 7 in. in diameter and 28 in. long is a pretty good-sized muffler

and will, I think, meet nearly all the requirements of truck service. There is nothing however to prevent standardizing the larger sizes if it is felt generally that this should be done.

FRAMES DIVISION

(13) *Running-Board Brackets*

[This report as printed on pages 391 and 392 was duly approved].

IRON AND STEEL DIVISION

(14) *Iron and Steel Specifications*

[The following changes and corrections were made in the report at the meeting of the Iron and Steel Division held Jan. 9, and approved at the Standards Committee and Society meetings.]

Page 397, Part VI, Definitions.—The definitions for "Normalizing" and "Annealing" should begin "A uniform heating above the . . . . "

Under Fig. 12 add equation

"Gage Length $d = 4.5 \sqrt{}$ Area of Cross-Section"

Under the heading "Construction," third paragraph, last sentence, delete "Plain ends for grips" and "may be used" and add "are recommended."

In the fifth paragraph, seventh line, delete "equals 4½ times the square root of the area" and substitute "conforms to the formula

"Gage Length $d = 4.5 \sqrt{}$ Area of Cross-Section"

In the fifth paragraph, lines 12 and 13, delete "Plain ends for grips" and "may be used" and substitute "are recommended."

Page 398—Delete Fig. 13 and the accompanying table. The last sentence of the first paragraph in the first column should read "Threaded or self-aligning ball-ends are recommended." Delete the entire third paragraph in the first column.

Page 399—Under the heading "Case-Hardening," second paragraph, delete "process of" and substitute "procedure after."

Page 400—Under "S.A.E. Steels 1010 and 1015," first paragraph, first line, delete "seamless." In the fifth paragraph, eighth line, change "strength" to "refinement" and in the last line change "core" to "case."

The following corrections were made in Brinell and Shore Hardness values.

Page	*Steel*	*Quench*	*Drawing Temperature, deg. fahr.*	*Hardness Numbers Brinell*	*Shore*
401	1020	Water	600	...	28
			900	...	27
	1025	Water	400	192	..
			600	192	..
402	1035	Oil	800	197	32
			900	192	31
			1000	187	31
			1100	183	30
			1200	179	30
			1300	170	29
	1035	Water	1200	183	..
			1300	174	..
403	1045	Oil	800	235	37
			900	...	36
			1000	223	34
			1100	212	33
			1200	207	33
			1300	192	31
	1045	Water	1000	229	..
			1200	212	..
			1300	197	32
409	3120	Oil	800	241	..
			900	217	..

Page	*Steel*	*Quench*	*Drawing Temperature, deg. fahr.*	*Hardness Numbers Brinell*	*Shore*
			1000	201	..
			1100	187	..
			1200	170	..
			1300	163	..
410	3130	Oil	800	...	44
			1000	...	37
			1100	...	33
			1200	...	31
			1300	...	29
411	3140	Oil	800	...	49
			900	...	45
			1000	269	41
			1100	...	38
			1200	...	35
			1300	...	33

Page 411—The curves of physical properties for Steel 3140 quenched in oil, shown in Fig. 29, should be replotted to the following points.

TABLE FOR STANDARDS COMMITTEE MEETING

Drawing Temperature, deg. Fahr.	Thousand Pounds per Square Inch			
	TS	YP	Red	Elon
800	176	152	44	11
900	156	132	50	16
1000	138	115	55	18
1100	124	99	58	19
1200	111	85	62	20
1300	102	70	64	20

Page 422—Heat-treament 9250-VIII and 9260-VIII, operation 6 should read "Quench in oil."

[With the corrections indicated above this report as printed on pages 392 to 422 was duly approved.]

THE DISCUSSION

F. P. GILLIGAN:—With reference to the reservation of the number 4 for molybdenum steels, the Division has taken no action toward standardizing molybdenum steel specifications but, feeling that it has to take into consideration the fact that this type of steel is being used and that it may be proposed as a standard S.A.E. steel in the future, considers it advisable to reserve number 4 for that type of steel to the end that those who are working with it can classify it by the same symbol.

Part II of the Iron and Steel Division Report, appearing on page 394 of the December JOURNAL, and entitled Specifications for Automotive Steels, is an existing standard conforming to that of the American Society for Testing Materials and has only been brought uptodate, no important changes having been made in it.

In part III, Chemical Compositions, there have been added steels 1015, 1030, 1040, 1046 and 1050. Steel 1015 is a carburizing type. Steel 1046 is primarily a carbon gear-steel; and 1030 and 1050 were added at the request of the American Gear Manufacturers' Association. No change is made in the screw stocks, steel castings or nickel steels. The manganese range on 2315, a carburizing type, has been lowered from 0.50-0.80 per cent to 0.30-0.60 per cent and nickel steel 2350 has been added at the instance of the American Gear Manufacturers' Association.

In the nickel-chromium series a 0.15-per cent carbon low nickel-chromium steel, 3115, has been added for carburizing purposes; it is a better carburizing steel than 3120.

Likewise a 0.15-per cent carbon steel, 3215, has been added and also steel 3245, midway between the 0.40 and 0.50-per cent carbon ranges to give a little closer range for certain gear requirements. Steel 3312 is proposed as a carburizing type for the 3300 series. The carbon ranges of steels 3320 and 3330 have been raised five points, changing them to steels 3325 and 3335, these ranges apparently reflecting general usage.

In the chromium steels, 5165 has been deleted, as there is apparently no use for it, and 5150 has been added for shafting material and for gear purposes. These constitute the only changes, most of them being additions to the present S.A.E. standard compositions.

Part IV, Steel Castings, is a copy of what has heretofore prevailed. No change is proposed in this specification.

Part V, Malleable Iron Castings, is a copy of what has prevailed in the past and is the same as the specification of the American Society for Testing Materials.

In proposing Part VI, Definitions, the Division recognizes the fact that it is difficult to get agreement on definitions pertaining to metallurgy. The definitions are proposed with distinct reference to their use in these specifications and not with reference to their general application.

Lighting Division

(15) *Bases, Sockets and Connectors*

[This report as printed on pages 422 and 423 was duly approved.]

(16) *Lamp Glasses*

[This report as printed on page 423 was duly approved.]

(17) *Tail-Lamps*

[This report as printed on page 423 was duly approved.]

Non-Ferrous Metals Division

(18) *Solders, Specifications, Nos.* 1, 2, 3 *and* 4

[In specification No. 1, Class B, the limits for tin should be 48.76 to 49.74 per cent. In Specification No. 2 the limits for tin in Class A should be 44.55 to 45.45 per cent and in Class B, 43.07 to 43.93 per cent. In Specification No. 3, Class B, the limits for tin should be 37.62 to 38.38 per cent.]

[With the corrections indicated above these specifications as printed on pages 423 and 424 were duly approved.]

THE DISCUSSION

MR. MOUGEY:—These specifications cover four grades of solder. Specifications Nos. 1, 2 and 3 are the same as American Society for Testing Materials specification No. B32-21. These specifications were printed in the form used in the S.A.E. HANDBOOK which gives the ranges as maxima and minima. The American Society for Testing Materials specification gives the range in tin as 1 per cent plus or minus of the content specified. The two methods of calculating the tin range will have a very small effect in the limits permitted, but the Division has decided to recommend that, instead of having specifications 1, 2 and 3 given with the limits as printed, the limits as calculated by the American Society for Testing Materials method be adopted. This will change the limits somewhat in some cases.

Specification No. 4 does not appear in the American Society for Testing Materials specifications since the lowest tin-content in those solders is 33 per cent. The limits for composition in specification No. 4 cover, it is thought, the same range as the American Society for Testing Materials would have covered if it had a similar solder specification.

(19) *Babbitt, Specification No.* 14

[After deleting the reference to iron in the table of composition the specification as printed on page 424 was duly approved.]

THE DISCUSSION

MR. MOUGEY:—Subsequent to a request from the Stationary Engine Division for a babbitt having a composition of approximately 70 per cent lead, 15 per cent tin and 15 per cent antimony, several babbitts were obtained from stationary-engine sources and analyzed. They were found to agree closely with American Society for Testing Materials specification No. B23-18-T, and the Division has offered Specification No. 14 to meet the request of the Stationary Engine Division.

(20) *Manganese Bronze, Specification No.* 43

[This specification as printed on page 424 was duly approved.]

THE DISCUSSION

MR. MOUGEY:—This specification as it is now printed in the S.A.E. HANDBOOK gives no satisfactory way of inspecting the bronze. The proposed physical test is the same as that of the American Society for Testing Materials, specifying the same tensile-strength and elongation requirements and the same preparation of test-bars. In the second paragraph, third line, of the specification, the expression "½-in. test-bar" should be changed to "standard S.A.E. test-bar," since there is a slight discrepancy between the standard S.A.E. test-bar and the American Society for Testing Materials test-bar. The difference is exceedingly small but the S.A.E. standard should be consistent with itself in these specifications.

(21) *Cast Brass To Be Brazed, Specification No.* 44

[This specification as printed on page 424 was duly approved.]

THE DISCUSSION

MR. MOUGEY:—Specification No. 44 covers cast brass to be brazed. This is a composition for which there is a demand at times, and the specification covers one of the most desirable compositions for this kind of material.

(22) *Brazing Solder, Specification No.* 45

[This specification as printed on pages 424 and 425 was duly approved.]

THE DISCUSSION

MR. MOUGEY:—Brazing solder is the material used in dip-brazing or in several other varieties of brazing as mentioned in the note on General Information. This specification covers a material that is common in the industry.

(23) *Commercial Sheet Brass, Specification No.* 70

[This specification as printed on page 425 was duly approved.]

THE DISCUSSION

W. B. PRICE:—This is a revision. We have simply changed the table of permissible variations in thickness to conform to those of American Society for Testing Materials specification No. B36-21.

(24) *Copper Sheet, Specification No.* 71

[This specification as printed on page 425 was duly approved with the addition of the following note under the table of "Permissible Variations in Thickness."]

These should be considered as general specifications.

Since copper sheet is used for many purposes where the requirements of the operations used are too particular to be specified by any of the ordinary physical tests, it is frequently advisable to submit samples or drawings to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations to which the material is to be subjected.

THE DISCUSSION

MR. PRICE:—This report is a revision of the table of ultimate strengths and elongations to replace that now printed in the S.A.E. HANDBOOK.

MR. GILLIGAN:—I would like to inquire what form of test is recommended for copper from 0.005 to 0.031 in. thick. The reason I raise the question is that we are confronted with a similar condition in the case of sheet steel and I was wondering if the sheet brass and sheet copper manufacturers have a satisfactory test-specimen for this thin sheet.

MR. PRICE:—We would use a section about ½ in. wide with about 2 in. between the punch-points. There should be a note, similar to the one appended to specification No. 70, stating that not very reliable results can be had on such thin material.

F. G. SMITH:—The recommended limits for tensile-strength are set, I believe, at such figures that if thin pieces having an average width of ½ in. and a 2-in. gage-length are tested and care is taken to see that they are straight so as not to tear, they will meet these specifications.

MR. PRICE:—We have not been able to develop anything that gives us more satisfactory results, so these figures have been set low enough to meet the requirements of test.

MR. MOUGEY:—We have made a great number of tests on thin sheets and find that the main trouble is in trying to test the small specimens in large testing-machines. The small test-specimens should be tested in a smaller machine to get a straight pull.

(25) *Naval Brass (Tobin Bronze) Rod, Specification No.* 73

[This specification as printed on pages 425 and 426 was duly approved. The discussion of this specification will be found with that of Specification No. 76 for Naval Brass (Tobin Bronze) Tubing.]

(26) *Naval Brass (Tobin Bronze) Tubing, Specification No.* 76

[This specification as printed on page 426 was duly approved.]

THE DISCUSSION

MR. PRICE:—Specification No. 73 is only a revision as a result of the insertion of "Tobin Bronze" in parenthesis, because this material is widely known by this name. Specification No. 76 is new and is submitted by the Division for adoption as S.A.E. Standard.

(27) *Brass Spring Wire, Specification No.* 80

[This specification as printed on page 426 was duly approved. The discussion of this specification will be found with that on Specification No. 88 for Brass Forging Rod.]

(28) *Phosphor-Bronze Spring Wire, Specification No.* 81

[This specification as printed on page 426 was duly approved. The discussion of this specification will be found with that on Specification No. 88 for Brass Forging Rod.]

(29) *Brass Forging Rod, Specification No.* 88

[This specification as printed on pages 426 and 427 was duly approved.]

THE DISCUSSION

MR. PRICE:—Specification No. 80 is a new one covering Brass Spring Wire; Specification No. 81 is new and covers Phosphor-Bronze Spring Wire. Specification No. 88 also is new; it conforms with Specification No. B15-18 of the American Society for Testing Materials.

PARTS AND FITTINGS DIVISION

(30) *Rod-Ends*

[This report as printed on page 427 was duly approved.]

THE DISCUSSION

F. G. WHITTINGTON:—The proposed revision of the S.A.E. Standard on Rod-Ends involves nothing other than adding the yoke-end boss diameters to the present standard on page C-8 of the S.A.E. HANDBOOK. These dimensions were decided upon in cooperation with the manufacturers of rod-ends and with car builders who make rod-ends. The Division found only two of the latter who deviated from the standard rod-ends. Both of them have now agreed to conform to the general practice.

The change in dimension K for the ⅞-in. size is made to correct an error in the original printing of the standard several years ago.

(31) *Taper Fittings for Plain and Slotted Nuts*

[This report as printed on page 427 was duly approved.]

(32) *Water-Pipe Flanges*

[This report as printed on page 427 was duly approved.]

(33) *Lock Washers*

[In Table 15 on page 429 the dimension *B* for the ¼-in. S.A.E. Standard Bolt was changed to 7/16-in. to correct a typographical error. With this correction the report as printed on pages 428 and 429 was duly approved.]

THE DISCUSSION

MR. WHITTINGTON:—The lock-washers recommended in revision of the present standard on page C5 of the S.A.E. HANDBOOK have been under discussion for a considerable length of time, the Motorcycle Division having brought up the question of the weights of washers for use against aluminum, and alleging that some of the washers are entirely too heavy for good practice. This recommendation also reduces the number of sizes by about one-third.

PASSENGER-CAR BODY DIVISION

(34) *Passenger-Car Door-Handles*

[This report as printed on page 428 was duly approved.]

(35) *Passenger-Car Doors*

[This report as printed on page 428 was duly approved.]

(36) *Rubber Bushings*

[This report as printed on page 428 was duly approved.]

(37) *Wiring for Beads*

[This report as printed on page 428 was duly approved.]

(38) *Body Nomenclature*

[At a meeting of the Passenger-Car Body Division, held Jan 9 the illustration and description for Fig. 51, and the brief description of this body in the Landaulet type, printed below Fig. 57 on page 431 of the Decem-

ber JOURNAL, were deleted from the Division's recommendation.

With the changes indicated above the report as printed on pages 430-432 was duly approved.]

THE DISCUSSION

E. G. BUDD:—This recommendation is in the nature of a revision of the present more or less obsolete nomenclature in the S.A.E. HANDBOOK, and is intended to bring about uniformity in nomenclature.

H. W. SLAUSON:—Should not Fig. 51 be entitled "close-coupled sedan" and retained as a distinctive type of body?

MR. BUDD:—It was the Division's thought that the builders will use various prefixes to describe that type. One will call it a "four-door coupe-sedan"; another a "close-coupled sedan."

SCREW-THREADS DIVISION

(39) *Pressure-Gage Connections*

[This report as printed on page 432 was duly approved.]

THE DISCUSSION

EARLE BUCKINGHAM:—The Division tried first to formulate one single standard but found that it would not meet the needs of the trade. Three sizes, including one alternate construction for the 1/8-in. standard taper pipe-thread are proposed. The pipe-thread size is intended for motorboat applications principally.

ALEX. TAUB:—The S.A.E. flared tubing connection is I think becoming antiquated and should be reconsidered. This recommendation is of no earthly use to us because we do not use this kind of a connection.

MR. BUCKINGHAM:—This recommendation is intended to cover all general applications; the 1/8-in. taper pipe-thread is to be used where the flared tube union connection is not desired. Provision can be made easily for tapping special gages to the standard 1/8-in. tapped hole.

MR. TAUB:—That would raise the cost to us about 60 per cent. We would rather design the tapped hole in the gage to fit the coupling and save that cost. We are doing it in other units and would want to do the same with the gages.

MR. BURNETT:—This recommendation has been considered by the gage manufacturers and, as it met with their approval, it evidently covers the requirements of the bulk of their production.

MR. CRANE:—I think that this report should be approved inasmuch as this flared-type connection is already an S.A.E. Standard. Personally I do not like it as well as the soldered union.

MR. BURNETT:—This report can be accepted and the subject considered again by the Division with the view perhaps of including the other type of connection referred to by Mr. Taub.

MR. BUCKINGHAM: — When the Division considered this subject as much information as possible was secured as to the various types of connections used. Practically all that I saw embodied the S.A.E. flared-union connection.

TRACTOR DIVISION

(40) *Tractor Drawbar Height*

[This report as printed on page 433 was duly approved, with the subject changed to "Tractor Drawbars" and the caption of Table 18 changed to "Tractor Drawbar Adjustments."]

TRANSMISSION DIVISION

(41) *Transmission Tire-Pump Mounting* (p. 433)

[This report as printed on page 433 was duly approved.]

(42) *Clutch Facings*

[This report as printed on pages 433 and 434 was duly approved.]

TRUCK DIVISION

(43) *Three-Joint Propeller-Shafts*

[This report as printed on pages 434 and 435 was duly approved.]

UNACCEPTED RECOMMENDATIONS

ELECTRICAL EQUIPMENT DIVISION

Generator Flange Mounting

[This report as printed on page 385 was referred back to the Division for further consideration particularly with reference to shaft diameters.]

THE DISCUSSION

MR. ANDREW:—The proposed change is intended to provide one armature shaft-end that can be used on both sizes of generator, which it seems desirable to be able to do.

R. G. THOMPSON:—Some engine builders use a No. 1 generator size and some a No. 2; they have practically the same work to do. Heretofore the standard called for one shaft-end for the No. 1 flange and a different shaft-end for the No. 2, so that in building a generator, one that would otherwise be the same, except for the flanges, there are two different types of armature shaft-ends. This recommendation is to make the armature-shaft extension the same for the No. 1 and the No. 2 S.A.E. Standard flange. Another feature of the recommendation is the provision for a washer, which is not included in the present standard. There is also a minor change in the location of the cotter-pin hole, so that it will not offset the drill center in the shaft-end.

C. MARCUS:—As I understand this recommendation it refers to changing the length of the threaded portion of the armature shafts to include a washer between the pinion or sprocket and the clamping nut. The threaded portion of the shafts is of the same length as in the present standard but is now made so that a washer can be included.

There is a larger diameter of shaft in the No. 2 flange, requiring a 204 size bearing, if ball bearings are used, instead of a 203. That is, if the bearing be the 203 in the No. 1 flange, it will have to be changed to the 204 and we will be standardizing a larger and more expensive bearing than the smaller flange would warrant. I think that is not intended.

CHAIRMAN B. B. BACHMAN:—There is 1/8-in. difference in the diameter of the shafts and the proposed change in the length will not accomplish the interchangeability desired as indicated by the discussion.

MR. CRANE:—As I understand it, this is a proposal to permit of putting a small flange on a large generator and a large flange on a small generator. If that is so, this revision will undoubtedly make it somewhat simpler for the manufacturer, even if the shaft diameters are different. Nothing would be different then except the pinion, which would be supplied by the maker himself who desired such an unusual combination of generator and flange sizes.

MR. MARCUS:—If that is the purpose of the change, there would not be anything against it except that it would be an unusual case. If it were desired to use ball bearings, let us say, in the case of the large flange with the small generator and small armature, there would have to be additional operations on the large flange

that would then become non-standard for the smaller bearing. That would cause additional working difficulty and overbalance the good effect to be obtained by taking care of what I think is a hybrid case.

MR. THOMPSON:—If it were possible to amend the report now to provide for a ¾-in. diameter shaft for both the shaft extensions, we would like to see it done. If that is not possible here, I suggest that we refer the matter back to the Division.

ENGINE DIVISION

Engine Testing Forms

[On page 391 of the December JOURNAL under "Specification Sheet B" the second paragraph should read "Under item No. 32, Lubricating System, Type and Description, provide for recording Cold Test and the Saybolt viscosity at 150 and 350 deg. fahr." Under "Log sheet C," the formula should read

$$B.Hp_c = B.Hp_o \times (P_s/P_o) \times (T_o/T_s)$$

and in the key to abbreviations, the words "of mercury" following "$B.Hp_o$" should be omitted.

With the corrections indicated above this report as printed on pages 390 and 391 was approved by the Standards Committee but was referred back, at the Society meeting, to the Engine Division for further consideration with relation to the temperatures specified for Saybolt viscosity.]

THE DISCUSSION

MR. FISHER:—The original intention of the Division was to revise the S.A.E. Engine Testing Forms so that the same forms could be used in testing practically all types of internal-combustion engine but it was soon found that this was not practicable, and therefore only a few minor changes in our present forms are now recommended.

In connection with specifying 350 deg. fahr. for the viscosity test it was assumed that this represents approximately the temperature of the cylinder wall and the sole object in including it in the form is to enable engine builders to make intelligent comparisons of the same engine on tests conducted in different laboratories or at different times. The viscosity of the oil is a considerable factor in determining the friction horsepower of the engine and thus it is a factor in determining the brake horsepower. The 150-deg. fahr. temperature was taken as a fair temperature for crankcases, particularly for heavy-duty engines, and is intended for the same purpose as the 350-deg. record.

A. C. BROWN:—The Bureau of Standards recommends that no other temperatures should be used than 100, 130, and 210 deg. fahr., as adopted by the Committee on the Standardization of Petroleum Specifications and the American Society for Testing Materials. The proposed temperature of 350 deg. is especially undesirable because at this temperature, using the Saybolt Universal viscosimeter, all oils would appear to have practically the same viscosity.

MR. FISHER:—That point was considered by the Division. It seemed to be the consensus of opinion that 150 deg. is nearer the crankcase temperature than 130 deg., particularly in the heavy-duty engines. I know from experience that it is not uncommon in the heavy-duty engines to find the crankcase temperature as high as 180 deg. In passenger-car engines a temperature of about 130 deg. is reached in the actual operating conditions.

P. J. DASEY:—The temperatures recommended are the ones at which the engines operate under maximum working conditions, and it seems to me that we should have some point at which the viscosity should be determined for these working temperatures. I feel that the temperatures of 100, 130, and 210 deg. fahr. were set at a time when they were considered for the lubrication of other than internal-combustion engines, and that they do not mean very much to us in our engine practice unless we have some means of checking the viscosities under conditions more nearly approaching those under which we operate.

If we can get a value at the working temperature, or something approximating it, we will be able to make direct comparisons of our data at operating conditions.

MR. MOUGEY:—It is my understanding that the National Petroleum Association has agreed to follow the American Society for Testing Materials in the matter of specifications for oil. There has been a big difference of opinion on oils and methods of testing them and I think it is very desirable to have the methods as nearly standard as possible. The oil that is used in the engine is not, of course, the original oil put into the engine because of crankcase dilution, which changes the viscosity considerably, especially on the cylinder walls where the dilution is high. This viscosity may be related in no way to the viscosity of the original oil. For that reason it seems to me that a standard method of describing the oil, such as that of the American Society for Testing Materials, is preferable to a method that tries to meet engine conditions that are not and perhaps cannot be known.

MR. DASEY:—There is a very large difference in oils of different bases. We all know that asphaltic-base oils are very much more viscous than paraffine-base oils when cold, but at high temperatures they are not as viscous as paraffine-base oils. Unless we have a range of viscosity figures that will show the decrease of viscosity of the different grades of oil, we are not in position to make a proper selection of oils. While it is true that there is considerable dilution in the application, depending upon the type of engine, the manifolds and other factors, it seems logical that we should have some fixed method of determining the value of the oil under operating conditions.

CHAIRMAN BACHMAN:—While it is true that other organizations have outlined specifications dealing with the determination of viscosity of oils, the Division has had something else in mind. Mr. Fisher summed up the matter rather clearly when he said that the purpose in putting this information on the testing forms is to provide for recording engine-testing data that will permit of directly comparing engine tests. Whether this will accomplish the desired results may be open to a difference of opinion.

MR. CRANE:—It is proposed to measure the viscosity at 350 deg. fahr. as representing somewhere near operating engine temperatures. The measurement of viscosity at this temperature is very difficult and uncertain, and I am convinced from my own experience and that of oil men that viscosity measured at 100, 130, and 210 deg. fahr., which are the present standard temperatures, will accomplish the same purpose. There is very little use of putting something on the engine test sheets and encouraging some of our members to think it is a feasible measure if we know very well that it is not.

PROGRESS REPORT

TIRE AND RIM DIVISION

Pneumatic Tires and Rims

[This report as printed on pages 432 and 433 was presented and considered as one of progress only.]

THE DISCUSSION

J. G. VINCENT:—I wish to make a statement about the Tire and Rim Division report, because it has been before us for some time, and we have not made apparently the progress we should have made. This matter came up very definitely at a Summer Meeting of the Society at Ottawa Beach.

At that time some of the members of the Rubber Association of America had in mind some rather radical revisions of the tire standards and to find out quickly what the consensus of opinion was among the tire manufacturers, I took it upon myself to write the presidents of the various tire companies. This eventually resulted in the meeting in Cleveland in November, 1920, at which the matter was thoroughly discussed. It was made very clear at that time that radical revision of the pneumatic-tire standards was not wanted. It was, however, recommended at that meeting that a committee be appointed by the Society, with members representing the Society, the Rubber Association and the National Automobile Chamber of Commerce, to study this matter from various points of view, engineering, economic and commercial.

A committee was duly appointed, consisting of H. M. Crane and myself, representing the Society; Mr. Viles, of the Rubber Association, and H. H. Rice, of the National Automobile Chamber of Commerce. After going into the subject carefully, it became clear to us that what was wanted, and the only practical thing that could be accomplished at the time, was to revise the S.A.E. Standards in a very modest way. We prepared a report and submitted it to the Rubber Association, and after making a few suggested changes, it was approved. We were assured that the National Automobile Chamber of Commerce would approve it and it was therefore printed in the December issue of THE JOURNAL for presentation at this meeting.

Since it was printed, however, some matters bearing upon it have come up within the Rubber Association, and we were waited upon by a committee this morning, composed of Messrs. Allen, Hale and Thacher, who told us that it was their opinion that it would be a mistake for us to pass upon this report for a standard today because they felt that, while it was substantially correct, they would be able within the next few weeks to give us some definite recommendations in line with this report, but with a few modifications that they think should be made. They also said that these recommendations will embody a standard that can be maintained without further changes for some time to come.

Mr. Clarkson, Mr. Crane and I considered the matter but were unable to confer with Mr. Rice. We understand that Mr. Viles concurs in the recommendation of this committee that waited upon us and we have decided that it would be wise to withdraw this report at this time, with the distinct understanding that we will get cooperation from the tire and rim interests, and that we will have something definite to report at the Summer meeting of the Society.

ATTENDANCE AT MEETING

The members of the Standards Committee and the Society and the guests in attendance were

Standards Committee Members

F. W. Andrew
B. B. Bachman
F. C. Barton
W. J. Belcher
R. M. Bird
A. K. Brumbaugh
Earle Buckingham
T. V. Buckwalter
E. G. Budd
R. S. Burnett
A. G. Carman
E. R. Carter, Jr.
D. F. Chambers
F. C. Chapman
W. A. Chryst
E. L. Clark
O. H. Clark
C. F. Clarkson
J. Coapman
J. R. Coleman
H. M. Crane
L. A. Cummings
C. S. Dahlquist
P. J. Dasey
C. N. Dawe
B. H. DeLong
J. B. Fisher
C. B. Franklin
E. S. Fretz
C. F. Gilchrist
F. P. Gilligan
G. E. Goddard
L. M. Griffith
C. O. Guernsey
F. W. Gurney
W. S. Haggott
O. B. Harman
E. W. Hart
C. G. Heilman
S. P. Hess
C. E. Heywood
M. C. Horine
E. A. Johnston
L. S. Keilholtz
G. W. Kerr
W. C. Keys
C. T. Klug
F. C. Langenberg
G. L. Lavery
G. C. Loening
H. R. McMahon
Charles Marcus
G. J. Mercer
C. A. Michel
M. B. Morgan
H. C. Mougey
C. T. Myers
A. J. Neerken
W. M. Newkirk
G. L. Norris
W. C. Peterson
H. S. Pierce
W. B. Price
C. B. Rose
C. F. W. Rys
A. J. Scaife
C. H. Sharp
L. D. Simpkins
C. W. Spicer
H. J. Stagg
W. R. Strickland
J. G. Swain
R. G. Thompson
Sam Tour
J. G. Vincent
K. F. Walker
J. M. Watson
F. G. Whittington
Ernest Wooler
G. A. Young

S. A. E. Members and Guests

W. H. Allen
V. G. Apple
C. R. Armbrust
E. L. Aurand
F. C. Bahr
W. C. Baker
G. A. Barnard
G. C. Brown
N. B. Burkness
J. T. Caldwell
K. H. Condit
J. M. Cranz
R. H. Cunningham
B. Darrow
W. L. Demsey
N. S. Diamant
W. A. Dick
E. Dickey
F. J. Druar
W. H. Eisenman
L. M. Ellis
H. S. Firestone
F. H. Ford
D. E. Gamble
G. W. Gilmer
J. E. Hale
W. J. Hart
P. M. Heldt
L. C. Hill
L. S. Horner
R. K. Jack
E. J. Janitzky
G. L. Kelly
T. S. Kemble
A. R. Kepler
Stephen Jencick
W. P. Kennedy
R. P. Lansing
J. Ledwinke
J. Linek, Jr.
M. T. Lothrop
W. T. Lutey
H. O. K. Meister
E. W. Miller
W. J. P. Moore
G. B. Muldaur
L. Ochtman, Jr.
L. Ottinger
W. J. Outcalt
J. F. Palmer
C. E. Phillips
S. P. Rockwell
R. F. Russel
E. F. Russell
G. A. Schanze
M. H. Schmid
W. G. Schneider
J. M. Schoonmaker, Jr.
J. R. Searles
R. H. Sherry
H. W. Slauson
F. G. Smith
H. H. Smith
R. O. Sperry
J. W. Stack
A. L. Swank
A. Taub
W. J. Taub
S. P. Thacher
F. L. Titchener
D. H. Tuck
G. A. Ungar
W. G. Wall
G. L. Wanamaker
J. F. Weller
J. J. Willard
W. E. Williams
A. D. Wilt, Jr.
O. W. Young

Harmony in Car Upholstery

By R. S. Quaintance[1]

Annual Meeting Paper

TAKING the artist's viewpoint, the author discourses on the subjects of color, color harmony and the psychological effects of color, as a prelude to a discussion of how the decoration of car interiors can be made most effective, this being necessary because of the elusive quality of good taste, a quality of appraisal rather than one of creation, and because esthetic taste depends upon the degree of mental development of the individual, although possessed in some degree by all.

The primary, secondary and complementary colors are defined and their mode of selection is described preliminarily to a consideration of color values and the selection of the most effective color-schemes, application of these principles being made thereafter to the decoration of car interiors, inclusive of comments on the most suitable fabrics and patterns. The author believes that color will be considered eventually in the automotive industry as being on an equal plane with lines and form.

HARMONY in car upholstery is a subject closely allied to color harmony in general; however, the decoration of car interiors is a new art in the sense that it is an old art newly applied. A car interior requires different treatment from that accorded a house interior; in fact, we must approach the subject from an entirely different angle because of its more or less public nature. Furthermore, owing to quantity-production methods that have made possible the extensive use of the closed car, it was essential in the past to exert extreme caution in designing fabrics for car builders that would prove acceptable to the greatest number of different personalities. The result caused restraint in conception to be the guiding rule. Unfortunately, this principle was not always recognized. The interior of a car has been treated at times as a piece of furniture to be upholstered as a boudoir with satins and hand-made lace, and all too often as a signboard whereon to write in blazing colors and patterns someone's ostentatious bad taste. It is time for a return to first principles. Good taste is an elusive quality, one of appraisal rather than of creation. The color scheme is the prime consideration in the correct decoration of motor-car interiors. The fabrics to be used are of importance also, but I will discuss the subject of color first.

In a broad sense color includes light and shade, and it is synonymous with light. It is safe to say that no subject has been more abused than color and I shall endeavor to clarify the entire subject of color harmony, or at least to convey a rudimentary knowledge of the subject so that the underlying principles, as applied to car interiors, can be understood.

The chief use of color is to beautify and, by its harmony, to appeal to the esthetic instinct. I believe that all persons possess esthetic taste, at least to a slight degree. We all know that taste is a matter of mental development. For instance, the child and the savage naturally prefer gaudy brilliant colors, but more mature and refined persons prefer somewhat subdued shades and tints. Many persons possess a natural color-sense. However, color knowledge is attained easily in sufficient measure to enable one to determine readily which colors are harmonious and which are not.

Color Harmony

Science maintains and proves every day that the orderly separation and coordination of simple facts will reduce the mysteries of yesterday to commonplace simplicities. Let us see what can be done toward simplifying the language of color and to define, in a measure, color harmony and its psychology.

We have the three pure colors of red, yellow and blue, as the basis of all other colors; they are elements in themselves, and cannot be produced by mixture. Accordingly, they are called primary colors; each of them in its full intensity differs widely from the others in tone and quality. A number of other colors are in the spectrum and are termed binary or secondary colors. They are formed by mixing equal parts of two primary colors. For instance, when we mix equal parts of red and yellow, we produce a binary color, orange; yellow and blue mix to form the binary color, green; and blue and red mingle into the binary color, violet, thus completing the circle. We now have six colors and have widened the field considerably.

In the application of colors to decorative design, the binary or secondary colors are vastly more interesting than the primary colors. Any color with two component parts is more interesting than a purely elemental color. For instance, orange has greater decorative value than either yellow or red, green has more "quality" than either blue or yellow and violet is decidedly more interesting than either red or blue. Like the primary, the secondary colors can be combined effectively with any or all of the neutral tones, white, black or gray. It is possible also at this stage to harmonize colors by using complementary or opposite colors.

Complementary colors are those which, if all colors were arranged around the circumference of a circle in proper order, would be exactly opposite the primary colors; in other words, by drawing a line from the red through the center of the circle, we would find that green is the complementary color. A primary and a complementary color form the strongest possible contrast to each other. It is not possible to find a color more different from red than green; they have nothing in common. However, these same colors have the peculiar power to enhance each other when placed side by side. Each seems to gain strength. A red apple looks redder when it nestles among the green leaves and the leaves look greener near the red apple. Another peculiar thing about the complementary colors orange and blue, yellow and violet and red and green, is the fact that they destroy each other when mixed together as in paints. A mixture of equal parts of any two complementary colors produces a neutral gray.

Color Psychology

To appreciate color harmony, it is necessary to know something of the psychology of color and the influence it exerts upon the emotions. It is a well-established fact that the entire personality is stimulated or depressed by

[1] Manager of sales promotion, Bridgeport Coach Lace Co., Bridgeport, Conn.

colors, and very many data are available on the effects of visual color-stimulus upon the blood pressure, upon muscular, mental and nervous activity and upon the mood, and these effects are evident in many ways.

The esthetic significance of color was recognized many centuries ago; in fact, much of the psychology of color appears in mythology. Xenophon reports a conversation between Socrates and Parrhasius in which the esthetic value of color is shown to have been appreciated by the early Greeks. Plato also discusses the beauty and symbolism of color and reveals his acquaintance with its ability to excite emotional response. The influence of color is positive, and so is the difficulty to analyze it. Has not everyone felt the influence, the purity of freshly fallen snow and experienced a feeling of resentment or guilt when this beautiful white cloak is wantonly soiled or disturbed?

The meaning of colors, their language, already is established by common consent throughout the ages. We cannot ignore it. Not all can understand the causes of some of their sensations of happiness or comfort, but many of them are definitely traceable to the proper use of color. The recognition of beauty of color and the finer feeling toward colors are dependent in large measure upon the taste of the beholder. To repeat, taste is largely a matter of mental development. The eye loves color. Whether conscious of it or not, all people react or respond to the influence of color. Color has power to attract attention, to stimulate emotion, to animate and cheer or to quiet and depress.

Color is not as well understood as it should be for the reason that artists have maintained it as their own private preserve. They built a barbed-wire fence about it and put up a sign reading, "Thou shalt not trespass." They contend that, aside from a few general principles of color harmony, the realization of satisfactory color arrangements depends on esthetic instinct.

The phase of color study which the charts cannot touch is a kind of inner shrine that we may term its psychology. Wholly apart from color sources, dimensions or harmonies, what are the effects different colors exert on personal feelings and emotions? Why do we feel cheered and enlivened by light tones of color and depressed by the darker tones? Why, for instance, is red a more exciting color than blue? Why do we speak of colors as warm or cold when there is no physical sensation of heat or cold? Why are orange, yellow and red called advancing colors and blue and violet termed retreating colors? All these and many other questions are answered in the study of color psychology.

It has been known for centuries that colors are either warm or cold, and scientists have established definitely that some colors are retiring an others are advancing. Colors are either stimulating or depressing, as well as either warm or cold. It is seen readily, when looking at the spectral band, that colors on the red side are warm and the colors on the blue side cold. We think of sunshine as being warm. Yellow is the color of the sun; hence, a tint or shade containing yellow is called a warm tint or shade. It gives us the feeling of vitality and warmth. It is the symbol of action, of courage. Red stimulates and excites. When we are stirred with strong emotion, such as anger, bashfulness or hatred, the red blood leaps from our hearts and flames in our cheeks. Red is far more attractive than yellow and is conducive to the thought of heat, an element that is lacking in yellow. Who has not felt the cockles of his heart warm and expand before an open fire? In a room otherwise dark and gloomy, it seems a living thing. Gilbert K. Chesterton expresses our attitude toward an open fire in these characteristic words:

> A queer fancy seems to be current that an open fire exists to warm people! It exists to warm their hearts, to light their darkness, to raise their spirits, to cook their chestnuts, to tell stories to their children, to make checkered shadows on their walls and to be the red heart of a man's house and hearth, for which, as the great heathen said, "a man should die."

Color Values

Red is a warm color of great power. Yellow, orange, the browns and their neighboring hues and tints are warm colors. All of the brighter colors are symbols of light and warmth and in this sense yellow is gaudy, gay and enlivening, and naturally emblematical of the sun.

Blue logically is associated with serenity, sedateness and cold calmness, and probably has been so associated through centuries of contemplation of the sky or heavens. Due to its being the color of the sky, it is characterized as dignified and soothing. It signifies melancholy as well as sedateness. Blue is everything that yellow and red are not. It is quiet, reserved and cold. We speak of the icy-blue stillness of the Far North, of cold steely blue eyes and of having the "blues" when we are conscious of a lack of enthusiasm over life's affairs. In fact, coldness is the outstanding feature of blue and is communicated in varying degrees by all colors that contain blue components.

The cold colors are predominantly restful. However, they may be either agreeable or disagreeable. Their associations determine their agreeableness and these generally operate through sub-conscious channels. The war colors generally are stimulating. But, as there are various degrees of stimulus, the warmer color also may be either agreeable or disagreeable.

Just why certain combinations of color are pleasing and others disagreeable, or even shocking, it is difficult to say. The question can be answered by stating that the combination is either harmonious or discordant. Harmony is merely a pleasing arrangement of colors; this is analogous to harmony in music, which is produced by pleasing arrangement of musical notes. In music, we know that rythmic experiences or sounds are much more agreeable than those which are non-rythmic. We must apply the same sort of rule to color. As an art, coloring is on an equal plane with music. However, as an exact science, music is far in advance.

Color Schemes

It is a well-established fact that the eye is pleased with a group of colors that show all of the primary colors in at least some degree. In color sensations the presence of all three colors appears to complete the color circuit. It is very difficult to explain this, and it must be accepted as a fact. As an instance, doubtless everyone has, at some time or other, tried the experiment of gazing intently at a round disc of strong red on a white background. If the red disc is suddenly removed and one continues to gaze at the white background, a green disc will appear. Green is a combination of yellow and blue. The eye has supplied the complement to the color that so filled it a moment before, proving that certain colors seem to call for or demand certain other colors.

Color harmony cannot be achieved by selecting any two or more colors from the spectrum at random. It is essential that the colors chosen be at equal intervals from each other. We find, here, an analogy in music.

Two harmonious colors can be chosen from a color cir-

cle by selecting two complementary colors as has been described; that is, two colors exactly opposite to each other on the color circle are harmonious. I will now describe how to locate three-color harmonies by using an equilateral triangle to insure an equal interval between the color steps. If we place the triangle with the apex at yellow, the other two angles will locate the other colors in the color scheme, red and blue; and in traveling around the color circle, we locate the secondary and the neighboring colors. Having a proper regard for area, the three colors in each group can be used together in respect to the hue and luminosity of each color, in any value or intensity, and with gray, white or black, and can be depended upon to produce harmony. However, do not misunderstand me; the primary and secondary colors located by this simple method would not be suitable for use in closed-car interiors.

Another method of arriving at a color scheme that combines all the primary colors but in far more subtle proportions is by varying the interval. Just as there are different intervals in musical harmony, the majors and the minors, there are different intervals in color harmony. This gives us what is termed a split complement. The three points of this triangle can be made to travel around the color circle and locate the different split complements. These combinations contain also all of the elements of the straight complement or all of the primary colors; but they are present in different proportions.

Decoration of Car Interiors

It cannot be emphasized too strongly that, in the natural expression of refined taste, the purer color must be used sparingly and with great care. The tints and shades or tones are to be favored. The chief function of the purer colors is emphasis only or, if one can so refer to it, the purer colors are for punctuation only. While it is agreed by most students that complementary colors are harmonious, there are certain conditions that must be considered, chief among which is area. For instance, green is the complementary of red. For certain purposes this combination is an excellent one. When applying it to a closed-car interior, we must neutralize the dominant hue. Professor Munsell has compiled a color chart which shows that red is twice as strong as green in what he terms "chroma." In this instance, we will regulate the area; so that our dominant color is green and considerably lowers the value of the red by darkening it. The green itself might well be grayed, preferably to an olive, and we then find, in applying the two complementary colors to a closed-car interior, that the color scheme has worked out to an olive-green cloth with a maroon stripe. It is a combination that is suggestive of spring and of the garb of nature and is representative of life, youth and freshness; a combination of warm and cold colors that is agreeable and restful, since the maroon stripe supplies sufficient life to tone-up the combination.

In passing it may be well to remark that nature supplies a wealth of harmony which must be studied to be appreciated. The student will observe quickly that nature employs a relatively small amount of pure colors. Even the beautiful sunsets are devoid of pure colors; all of the beautiful effects arise from ever-changing combinations of tints and shades.

A point to be borne in mind in regard to harmony in car upholstering is the fact that the less obvious the color element is, the more quality the different tones possess. This is applicable equally to color harmony in other fields.

The warmer tones are to be preferred for use in a closed car as against the colder tones. By those who have understood the subject, the warmer tints have been selected with a view to making the interior cheerful and inviting in its appeal, and to make it as pleasant as a well-appointed drawing-room in its season of greatest usefulness, winter. The same interior can be made cool, quiet and restful during summer, by the use of slip-covers having a color scheme based upon the cold side of the color circle. Slip-covers serve other purposes, chief among which is the protection of the upholstery from dust and dirt during periods in which the windows frequently are lowered when driving.

A still different kind of color harmony that, I am sorry to say, is extremely popular with many car-builders, is what is termed a mono-chromatic group. This is made up of two or more tones of the same color. It is the most unobtrusive and conservative harmony scheme possible. It is always safe, but seldom interesting. There is, however, an even more severe treatment, that of employing a single solid tone. This practice requires painstaking care in the selection of laces, curtains, curtain cords and other trimming accessories to insure perfect matching. I have seen some excellent examples of this type in the products of custom body-builders, but I do not commend its use to large manufacturers. This treatment would not wear well with some personalities; it would become extremely monotonous and probably tiresome.

In the mono-chromatic harmonies, those employing two or more tones of the same color and any other schemes except the solid tone, it is possible to give the interior that natural balance of light over darkness that is considered of prime importance in all decorative fields. In this case the floor covering would be of the darkest shade, the body cloth a trifle lighter, and the trimmings and head lining, if one is used, of a still lighter shade. In interiors of this nature it is possible to make the color scheme interesting by the use of one or more bright spots such as an enameled handle or vanity case, or by using other interior fixtures. This should be of a color complementary to the dominant color. If we must have mono-chromatic car-interiors, let us at least liven them up. If we insist that the cloth manufacturer supply us with fabrics containing two or more neutral shades, then let us *save* the interior; let us liven it up by the intelligent use of spots of color in the other interior fittings.

I wish to urge, however, that we be reasonable. Judging from the descriptions I have read of the cars shown at the recent Paris Salon, our European friends have achieved some remarkably grotesque discords in this line; apparently, this is a reaction from the recent war. Some of the cars shown must have been extremely ludicrous; nevertheless, we can learn much from the Europeans. Not all of their creations are to be classed as freakish; in fact, all Latins are more artistic than Saxons, as a rule and, generally, they are much more fond of color.

Fabrics

There are three general types of fabric, cotton, wool and mohair. Of the first, cotton, little need be said. Cottons are used generally in the cheaper cars only, although the cotton velours had an extensive run in the medium-grade cars during the war period, as did the cheaper cottons also. These velours, while giving a rich luxurious effect, are not as serviceable as mohairs or woolens. The mohairs woven from the hair of the angora goat are extremely serviceable and have enjoyed several years of popularity. But the fabric that seems to be the most desirable from all angles of style, wearing quality

and appropriateness is the various kinds of woolen cloths. They vary in weaves and weights and a particular type can be found for any upholstery purpose.

A point to be borne in mind when selecting fabrics is that any pronounced figure will soon grow extremely tiresome. The eye requires complete rest in a closed car, rest from the continuous motion outside. The influence of the interior should be one that is felt rather than seen; for this reason the brocades, tapestries and chintzes, or other furniture upholsteries, have no place in the correctly appointed motor-car. The pattern should be small and unobtrusive and appear in the body lining only.

Some manufacturers have experimented extensively with woolen cloths and today are weaving a cloth on looms especially designed for automobile fabrics. Special finishing machinery has been built to impart a broadcloth finish to all woolen cloths. A fabric that promises to become extremely popular is the new worsted cloth. Some of this is all worsted, and some grades are only worsted-faced. These cloths trim well and have unusual wearing qualities. Another new fabric that has great promise is the mohair sateen, a flat woven mohair. This can be made in a wide variety of shades and various patterns and, strange as it may sound, it is guaranteed by the manufacturer to outwear the car.

In conclusion, I want to enter a plea for more color; more color in the interior and more color in the exterior. We literally have worked the funereal color, black, to death. For years we have painted the majority of our cars black. We have had too much of it. We should brighten the cars with color. As a result of the continued practice of using black, we have killed many an owner's pride in his car. When one drives home in a new car in these days, it is impossible to feel that one is creating any stir in the neighborhood. In fact, one's neighbor is very apt to remark over the back fence, "I see you got the old bus washed up."

Recently, while in Havana, I was very agreeably surprised to note the difference in the appearance of a long line of automobiles from that noticeable here. Every car in the line was clean and shiny and fully half of the cars were painted in colors other than black. They are very fond of color in Cuba but, to be frank, they know how to use it. A parade of automobiles in Havana is an interesting thing to watch.

Much attention has been devoted in the automotive industry to the subjects of line and form. Color has not yet played a leading part but, sooner or later, color will come into its own and be on an equal plane with line and form. When this occurs and the automotive industry comes to an appreciation of the commercial value of beauty in color, we will find that color will not only supply the atmosphere and the drapery, but play a dominant rôle.

THE THOMPSON AUTORIFLE

THE development of a semi-automatic self-loading military rifle, weighing less than 10 lb. capable of firing high-powered cartridges, has been a perplexing problem of gun designers throughout the world. Self-functioning and automatic arms have been operated by (*a*) the blow-back of the gas against the head of the bolt; (*b*) a gas-operated piston that in turn operates the bolt; and (*c*) the force of recoil. With the advent of the Thompson autorifle and the Thompson submachine-gun, another system of automatic breech-closure is added, namely, the self-acting lock in which the bolt is in the form of a wedge or a screw and which in itself without other accessories constitutes at once an automatic lock and release. This is accomplished by the principle of adhesion, about which, outside of the experiments of Gen. John T. Thompson and his associates during the last few years, little is known. A study of this new principle shows the advantages of the self-acting lock by reason of its extreme simplicity and consequent saving of weight, overcoming at the same time many of the basic engineering problems involved, as the weight thus saved can be placed where most needed. This principle was observed and patented by Com. John Blish of the United States Navy, and presented to a special Board of Naval Ordnance before the world war.

The first piece of mechanism that successfully demonstrated the Blish principle was the Thompson submachine-gun, now generally known and on the market. In this form the simple wedge was successfully used as a self-acting lock. The next development of the principle has been the Thompson 0.30-caliber autorifle, in which the screw form of bolt was utilized as the self-acting lock. The autorifle has been basically considered as an engine; in fact as a double-acting gas engine in which the bullet and the bolt have motions of translation in opposite directions and are moving pistons.

Those experienced in the actual use of automatic guns are almost unanimously agreed that the oiling of cartridge cases insures more certainty of action. In fact, cartridge-case oiling was prevalent in the field during the world war. This practice was accomplished crudely with an oil-can before loading. The reason for this is obvious when it is realized that extraction, which is the heart of the automatic problem, requires varying forces. The extraction pull necessary for cartridges has a wide variance due to the adhesion of the case to the chamber and also because in some gas and recoil automatic guns the instant of applying or timing the pull is not always the same for each shot, especially where the rate of fire can be regulated in such guns. The autorifle is loaded in exactly the same manner as the service rifle. In doing so, however, the cartridge cases are automatically oiled. This changes the back-pressure on the bolt from that known to be exerted by dry cartridges. Hence, after exhaustive tests, its use in the service rifle has been discouraged by certain experts. However, in guns specially designed and with mechanisms timed particularly for such pressures as in the Thompson mechanisms, this point is safely taken care of and large factors of safety are secured. As the bullet is neither oiled nor greased, the ballistic qualities of the bullet remain unaltered. The mechanism, however, gives a considerable reduction in recoil with corresponding advantages in the accuracy of firing.

In appearance and general form, the Thompson autorifle is a replica as far as possible of the present United States service rifle. In fact, out of a total of 95 component parts for the United States Model 1903, 30 of the total 86 parts of the autorifle are the same as in the service piece. The design allows the autorifle to be dismantled completely and assembled rapidly. Dismantling for replacement of moving parts is accomplished without the use of tools and is simple. Comparing the gun mechanism proper consisting of all parts necessary for free functioning the autorifle has 44 parts contrasted with 42 for the United States Model 1903. The total weight of the autorifle is 9 lb. 10 oz.

Magazines are either detachable holding 10 or 20 shots or fixed as desired, the latter holding the regulation five cartridges. The autorifle can be used conveniently as a hand-loaded weapon when desired, reserving the semi-automatic feature for emergencies. The mechanism functions equally well with powder charges 40 per cent below or above normal pressures of 50,000 lb., without adjustment of any kind.

American Marksmanship

Turning from the mechanical aspects of the military semi-automatic problem to the tactical considerations of the case,

(*Concluded on page* 144)

Air-Cooled Engine Development

By Charles L. Lawrance[1]

Annual Meeting Paper *Illustrated with* Drawings

The development of air-cooled engines for aircraft never made much progress until the war, when the British attempted to improve the performance of existing engines by a series of experiments leading eventually to the development of aluminum cylinders with steel liners and aluminum cylinder-heads with a steel cylinder screwed into the head. The advantages of these constructions and the disadvantages of other types are discussed. Results are reported of tests at McCook Field on a modern cylinder-design of this type showing good results, that lead to the belief that large air-cooled engines will be produced in the near future, equal in performance to water-cooled engines of the same power. It is claimed that, at present, there is nothing to choose in performance between water-cooled and air-cooled engines of about 25 hp. per cylinder, and that air-cooled engines of this size can be built successfully of the same compression-ratio and having the same fuel-consumption as high-compression water-cooled types.

An explanation is given of the reason for the advantages of aluminum cylinders and head constructions, and a chart is presented showing the temperature on the front and the rear of a large air-cooled cylinder of high output. The question of the cylinder-wall temperature of air-cooled and of water-cooled engines is discussed, and it is indicated that there is not much difference in temperature between the two types. The water-cooled engine is at a disadvantage on account of the number of heat transfers from one medium to another before the heat reaches the air. A statement is given of the reason air-cooled engines can perform satisfactorily with less cooling area than is required for water-cooled engines.

The subject of the resistance of airplanes having air-cooled and of those having water-cooled engines is discussed, attention being drawn to the fact that little is know of the best methods of installing and cowling these engines. Various suggestions are made for possible future development of cowling, to permit airplanes equipped with air-cooled engines to offer as little resistance as those equipped with water-cooled engines.

Valve Operation

Fig. 1—A 25-Hp. Air-Cooled Anzani Engine

THE use of air-cooled engines in aircraft is not of recent origin; but, except in the field of rotary air-cooled engines, it is only within the last few years that it has attained any importance or been regarded seriously by most aircraft and powerplant engineers. From the time that Bleriot crossed the English Channel in an airplane equipped with a 25-hp. air-cooled Anzani engine, such as is shown in Fig. 1, there has been some steady development of air-cooled engines, limited, however, to very few companies. For a long time the Anzani, Nieuport, R.E.P. and Gnome engines were about the only well-known air-cooled powerplants built, of the type shown in Fig. 2. I believe it is of interest to compare the design of several of these early engines with that of some of the later types. It is not my intention to take up the subject of rotary air-cooled engines, as the production of this type has been practically abandoned.

The Nieuport engine was a great step in advance. It had mechanically operated valves, cylinders having good fin-area and would be considered more or less uptodate

[1] M.S.A.E.—President and chief engineer, Lawrance Aero-Engine Corporation, New York City.

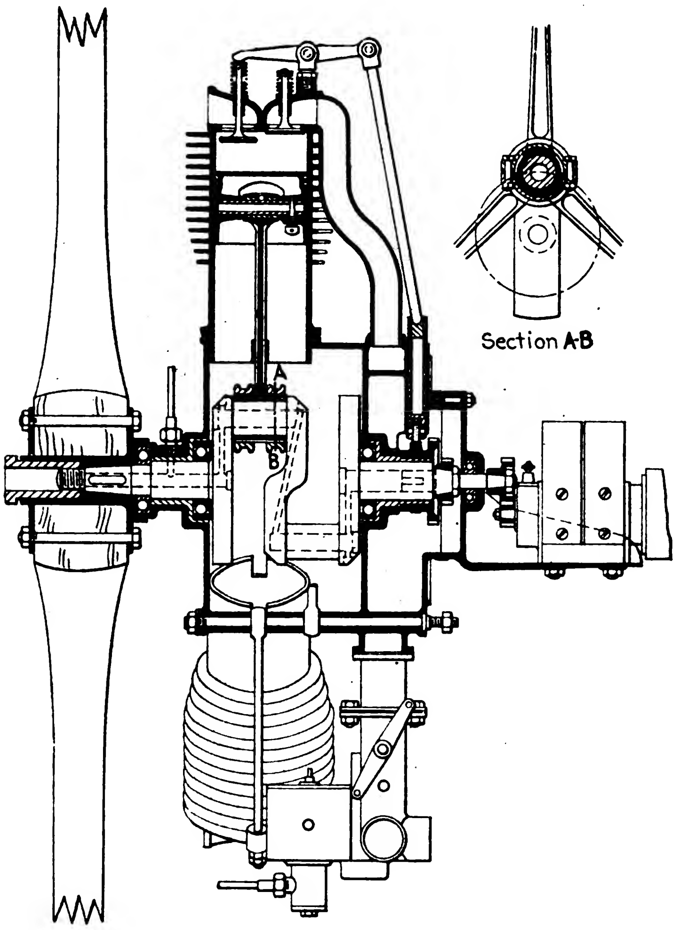


Fig. 2—Sectional Elevation of the Anzani Engine

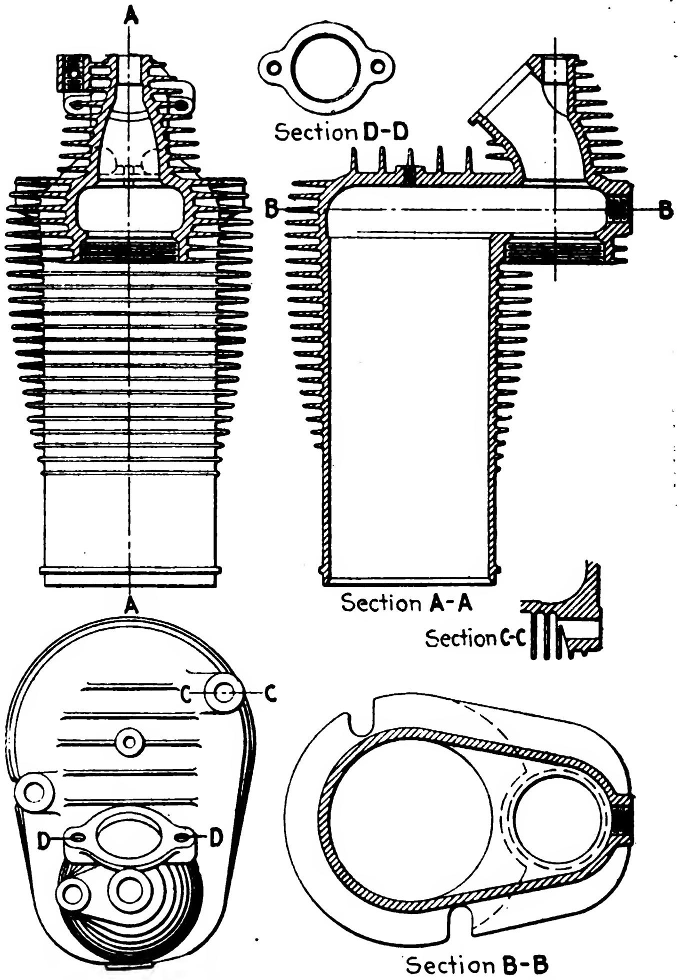


Fig. 3—The Original Air-Cooled Cast-Iron Cylinder Developed by the Royal Aircraft Factory

at present, but this development was abandoned after an aircraft accident in which Mr. Nieuport was killed. The Renault Co. brought out an 8-cylinder and a 12-cylinder air-cooled engine some years before the war, and some of them are still running. They are of the V-type. The cooling is derived from a centrifugal blower, the air being carried to the cylinders by a form of cowling. The De Dion Bouton Co. brought out a similar engine shortly afterward. All of these engines were of low mean effective pressure, with the possible exception of the Nieuport, and it was agreed by almost everyone that it was not practicable to build air-cooled cylinders of greater than approximately 4.5-in. bore and that even with these sizes it was impossible to obtain a high performance.

British Experiments

The British, with a view to improving the performance of existing Renault engines and the Royal Aircraft Factory engines, which were more or less similar, started a series of experiments about 1916 which carried them very far. The original Royal Aircraft Factory cylinder shown in Fig. 3 developed only a mean effective pressure of 85 lb. per sq. in. and had a fuel consumption of 0.67 lb. per b.hp-hr. It is easy to see that this cylinder had entirely inadequate exhaust-valve and head cooling. An attempt was made first to improve this cylinder by casting it in aluminum with slight modifications of design and with a shrunk-in steel liner. This is, so far as I know, the first instance in which the construction, shown in Fig. 4, was used. In this cylinder the mean effective pressure was no better than that of the cast-iron cylinder, but the fuel consumption was reduced to 0.57 lb. per b.hp-hr.

These two cylinders were of 4-in. bore, and it was decided to build an improved design of cylinder of 4.5-in. bore having overhead valves. This also was an all-aluminum cylinder with a shrunk-in liner and steel valve-seats cast in the aluminum head, as shown in Fig. 5. It is easy to see from the location and cooling of the valves and the large fin-area that a great improvement was to be expected, and this engine actually showed a mean effective pressure of 108 lb. per sq. in. and a fuel consumption of 0.54 lb. per b.hp-hr. This cylinder was followed by a still larger cylinder of 4.75-in. bore, but

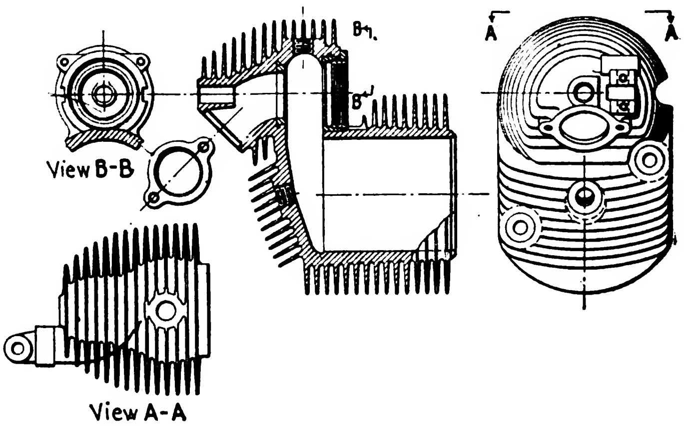


Fig. 4—The Royal Aircraft Factory Air-Cooled Aluminum Cylinder Designed for a Steel Liner

of the same general design as shown in Fig. 5. It is very much like the type used today in air-cooled engines. It showed a mean effective pressure of 118 lb. per sq. in., a fuel consumption of 0.505 lb. per b.-hp-hr. with a compression-ratio of only 4.6 to 1, which is almost as good as can be obtained today under the same conditions.

A number of improvements were then carried on with a view to finding the best material and construction for a cylinder liner. It was found that the shrunk-in construction, although satisfactory when the engine was new, permitted the oil to get between the cylinder wall and the liner, thus decreasing the cooling efficiency after the engine had been run for a time. Our experience, however, has shown that where the cylinder and liner were properly machined and shrunk together with the proper fit, the falling-off in power after a great many hours of running is negligible and the increase of fuel consumption very small.

The construction shown in Fig. 6 has great advantages over the method already mentioned as having been adopted by the British, where the liner was clamped in place against a shoulder at the top with a view to keeping out the oil. A clearance between the aluminum holding-down flange at the base of the cylinder and the crankcase is necessary in this construction. On account of unequal expansion of the liner and the cylinder, the tightness of the joint between the liner and the top of the cylinder is an unknown quantity, when the engine is hot, and the question arises regarding the proper tension of the holding-down bolts that leaves too much to the personal element. This construction is shown in Fig. 7. In addition to the trouble due to oil leakage, an examination of the cylinder and the liner after running showed a considerable lack of contact that did not, however, appreciably affect the performance for cylinders up to 4.75-in. bore, but for larger bores it was thought desirable to find another method of construction. Accordingly, experiments were made by casting an aluminum head on a steel cylinder, as shown in Fig. 8. This construction did not prove altogether satisfactory, according to a British report, as it was hard to get a bond between the two

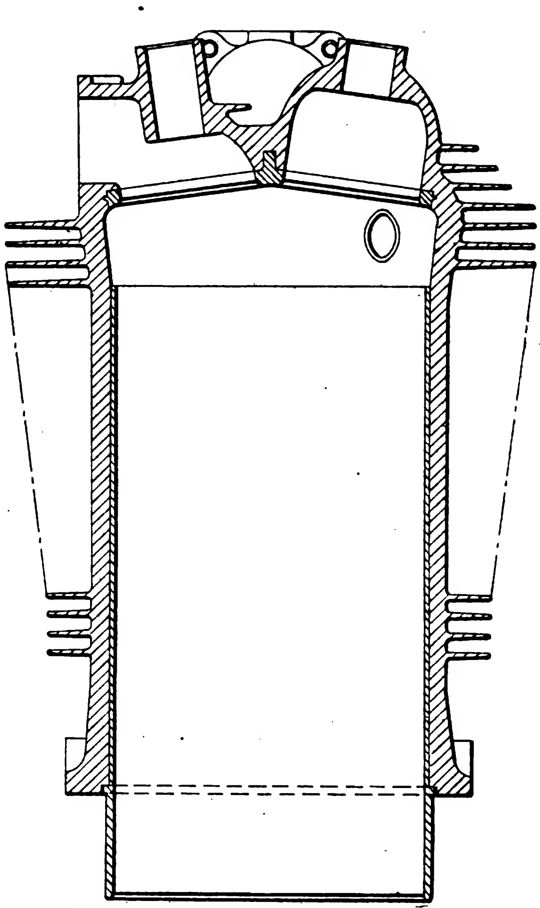


Fig. 6—The Lawrance Model L Cylinder

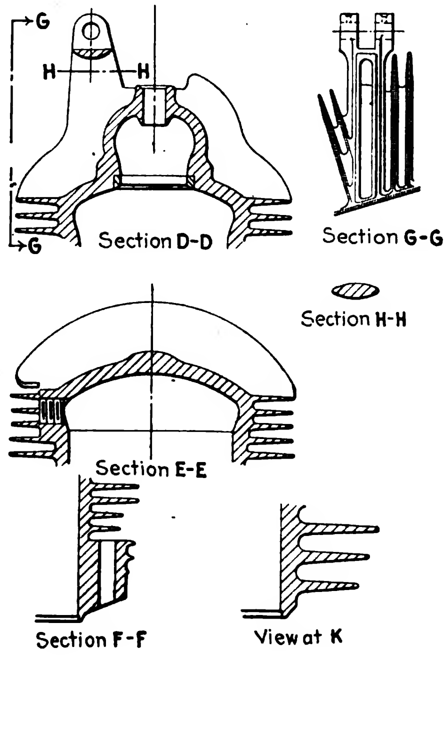


Fig. 5—A British Air-Cooled Aluminum Cylinder Having a Shrunk-In Steel Liner and Steel Valve-Seats Cast in the Cylinder-Head

metals, especially because the difference in their coefficients of expansion tended to break down any contact that originally existed. These experiments were corroborated by experiments at McCook Field on a Weinberg engine recently. They showed not only that this was true, but also that the stresses due to shrinkage in casting caused the aluminum head to crack, and this method of construction has been abandoned.

Types of Engine

During the latter part of the war several large radial air-cooled engines were brought out by the British. In these engines it was thought to be too much of an experiment, probably on account of the large cylinder sizes required, to use an aluminum head and they were therefore built with steel cylinders and heads more or less on the lines of rotary radial-engine practice. One of these, the A. B. C. Dragonfly, having a 5.5-in. bore and a 6.5-in. stroke, was designed, built and put into large production without having had much testing. Fig 9 shows the A. B. C. Dragonfly engine cylinder. This engine never proved satisfactory, on account of cooling and other troubles. It will be seen that the provision for cooling the head of the cylinder is practically nil and, in view of this, the low brake mean effective pressure of 100 lb. per sq. in. obtained is not surprising.

Somewhat later, the Jupiter-Cosmos engine shown in Fig. 10 was brought out. This engine had even larger cylinder dimensions, a 5.75-in. bore and a 7.50-in. stroke. An attempt was made here to cool the head by an aluminum cover containing the valve-ports, which was bolted to the top of the steel cylinder-head. This cover was supplied with cooling fins. This engine showed marked improvement over the A. B. C. Dragonfly engine in cooling and other details, but it was found that the contact between the aluminum cover and the steel cylinder-head was poor, due to warping of the two parts in question. A

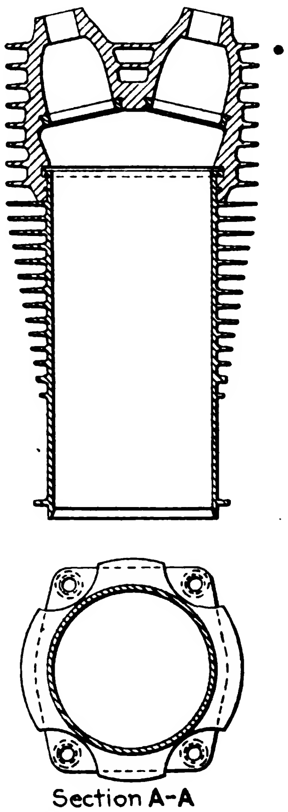


Fig. 8—A Type of Air-Cooled Cylinder Subsequently Developed by the Royal Aircraft Factory in Which the Aluminum Head Is Cast on the Steel Cylinder

radial engine having cylinders of this type was built in the United States by the Wright Aeronautical Corporation, having a 5⅝-in. bore and a 6½-in. stroke, which

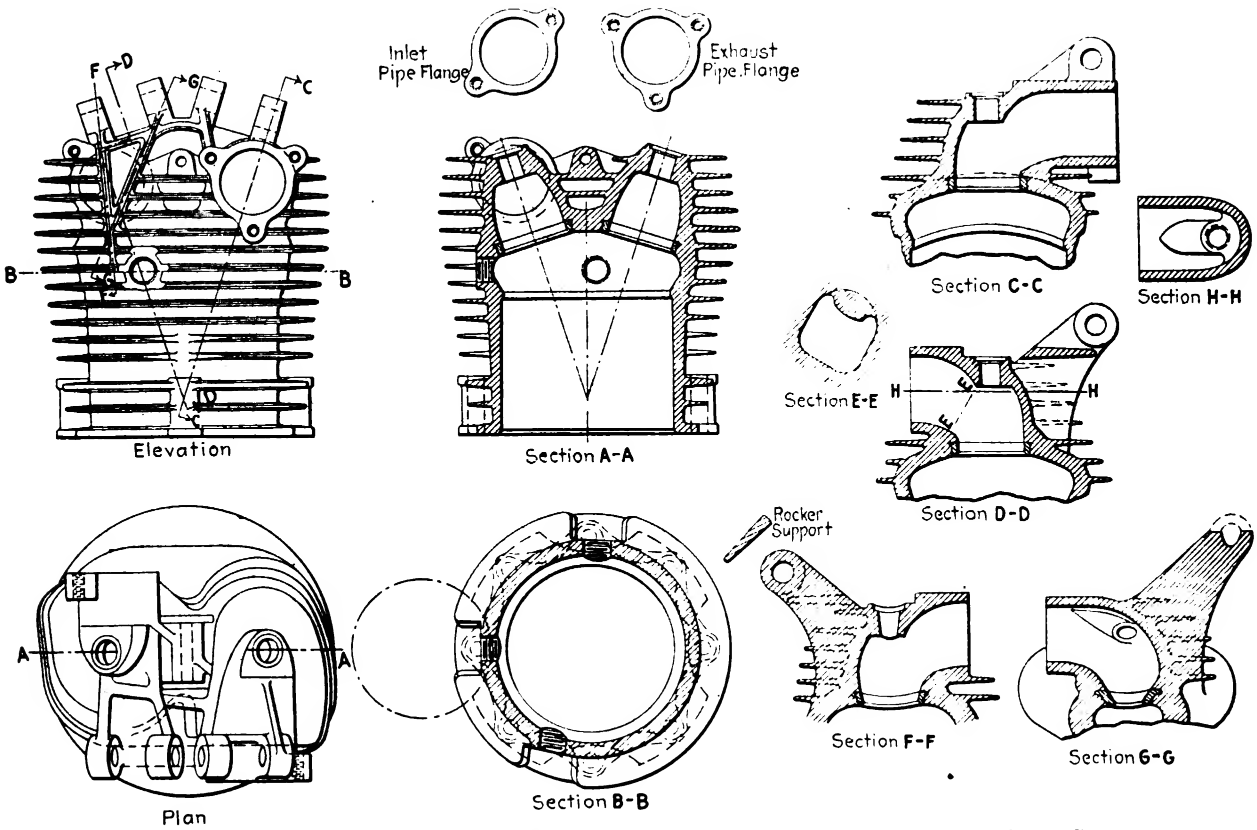


Fig. 7—The Royal Aircraft Factory Air-Cooled Aluminum Cylinder with Flange and Bolt Construction

showed a somewhat better performance; but this design of cylinder has been abandoned since in favor of a new type that has been developed for this engine. It is giving good results and will bring the performance to par with the best water-cooled engines.

Appreciating the difficulties encountered in these designs, the British carried on some experiments and produced a cylinder construction in which a steel cylinder is threaded into an aluminum head, that appears to be satisfactory. Experiments along these same lines have been made recently at McCook Field, in which the cylinder and head are assembled as already described after the head has been heated to about 700 deg. fahr., with a sufficient shrink-fit to make a very tight job, as indicated in Fig. 11. This construction appears to combine all of the advantages of the various systems already described. The steel cylinder has sufficient cooling-area on the barrel, and is of very light construction. The thick aluminum head of high conductivity and large fin-area is particularly suited for the dissipation of heat.

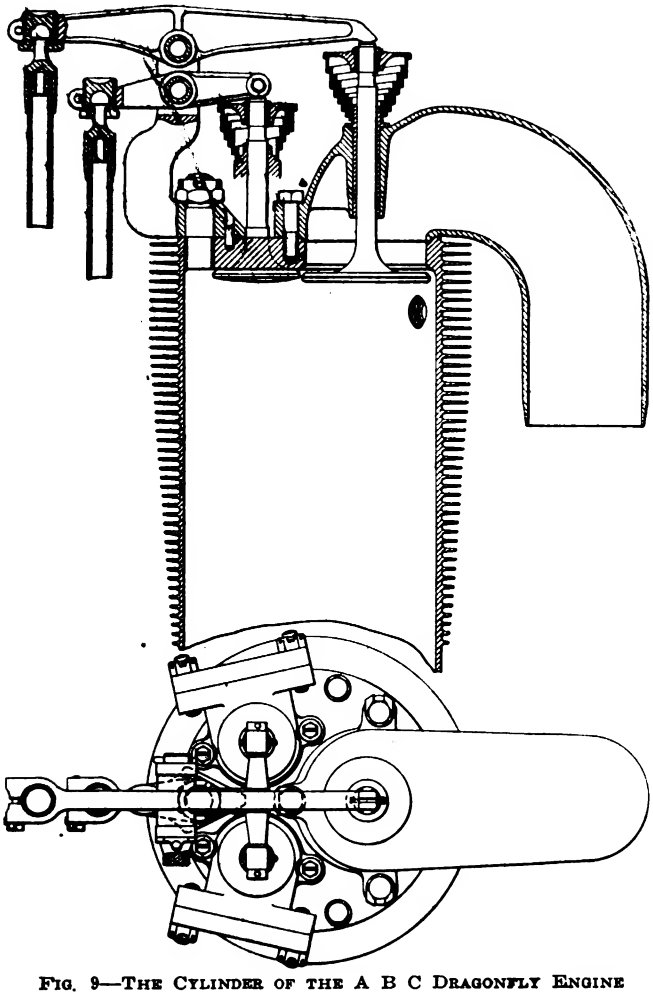


Fig. 9—The Cylinder of the A B C Dragonfly Engine

A cylinder of this type having a 5⅝-in. bore, a 6½-in. stroke, and a 5.3 to 1 compression-ratio has just been completed at McCook Field and been run in some preliminary tests. The fuel used was composed of 50 per cent of benzol and 50 per cent of average gasoline, and the results are shown in Table 1.

These tests were almost the first ones made with this cylinder, and were to test it for mechanical soundness rather than for performance. They were made with a casual carbureter-setting and are not by any means the best results obtainable. From this it might be inferred

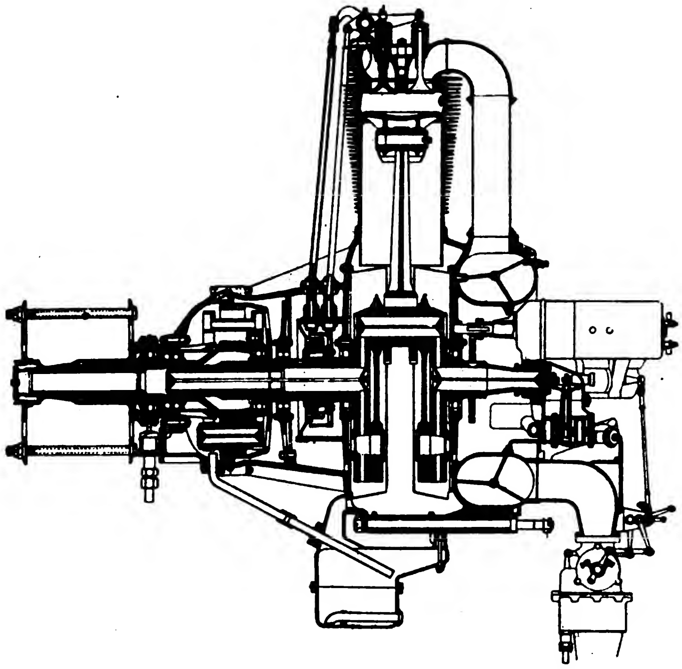


Fig. 10—Elevation Partly in Section of the Jupiter-Cosmos Engine

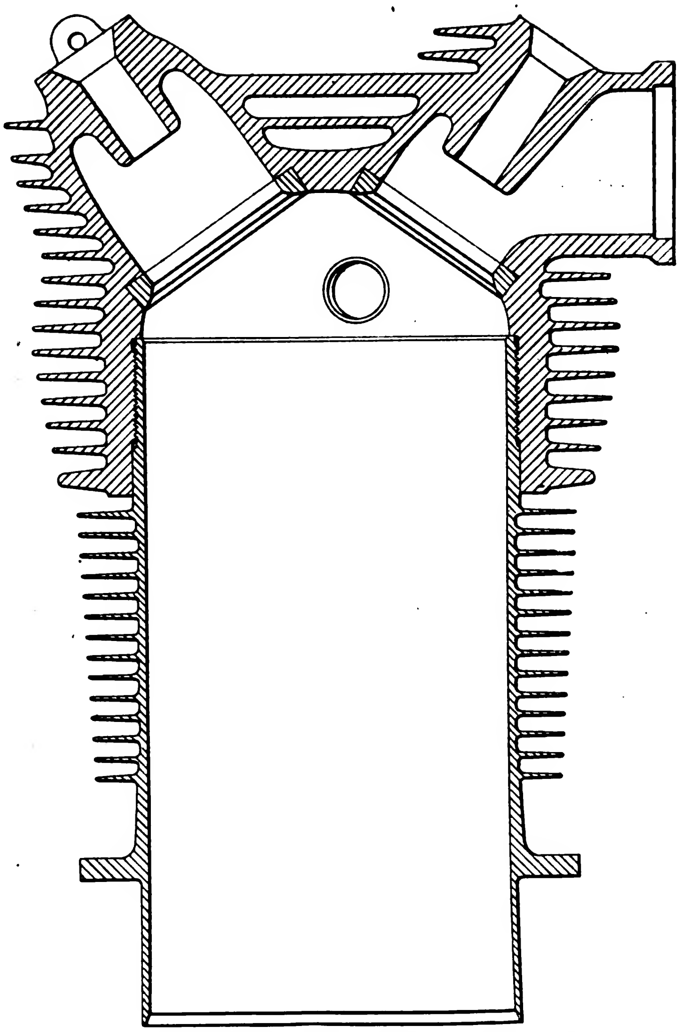


Fig. 11—An Experimental Steel Cylinder with a Screwed-On Aluminum Head That Was Developed by the Air Service at McCook Field

TABLE 1—PRELIMINARY ENGINE-CYLINDER TESTS AT MC COOK FIELD

Speed, r.p.m.	Power, b. hp.	Brake Mean Effective Pressure, lb. per sq. in.	Fuel Consumption, lb. per b. hp-hr.
1,430	37.4	128.2	0.56
1,590	42.3	130.2	0.56
1,670	44.6	130.8	0.56
1,770	47.3	130.8	0.56
1,900	49.5	127.6	0.56

that a construction having a cylinder consisting of a steel barrel to which are bolted an aluminum combustion-chamber and head, as illustrated in Fig. 12, would have the advantage of cheapness without any loss of efficiency. Experience has shown, however, that this is not true. For efficient cooling of the combustion-chamber, the aluminum must be carried some distance down the sides of the cylinder barrel to obtain sufficient cooling area. It has been shown also that a highly-domed head is desirable, as is indicated in the cylinder illustrated in Fig. 11, thus permitting a greater number of cooling fins in close contact with the head of the cylinder. But experiments have still to be made for determining the relative merits of size, shape and number of cooling fins, in connection with cylinder diameters and high compression-ratios before a definite conclusion as to the practical limit and size of the air-cooled radial-type engine can be reached.

Air-Cooled versus Water-Cooled Engines

The result of all these experiments on air-cooled cylinders covering a period of years has brought the art to such a point that air-cooled engines of approximately 25 hp. per cylinder are being produced commercially that have the same performance ability as the best water-cooled engines. This can be established by a comparison of the performance of an air-cooled engine and a water-cooled engine of approximately the same power. We will take for comparison a typical water-cooled V-type eight-cylinder engine and the Lawrance Model-J, nine-cylinder air-cooled engine. In neither case is the horsepower the maximum that can be or has been obtained; it is the average horsepower likely to be obtained in service. Table 2 shows this comparison.

It will be noticed that there is very little difference between these engines. The fuel consumption of the water-cooled engine is lower than that of the radial air-cooled engine on account of the higher compression-ratio of the former. Both engines can show a considerably lower consumption if regulated for this, of course; however, this is at the expense of the horsepower.

Including 68 lb. for a radiator and 76 lb. for water, the weight of the water-cooled engine is 621 lb.; the air-cooled engine weighs 426 lb. complete. This saving is due to the air-cooling and the more compact arrangement of the radial engine. Experience with air-cooled cylinders of this type has shown that it is possible to increase the compression-ratio to the same extent as in water-cooled engines, and that a fuel consumption equaling the best performance of water-cooled types can be obtained. Tests of a three-cylinder engine having a volume of 75 cu. in. per cylinder and a compression-ratio of 6.2 to 1, using one-half benzol and one-half aviation gasoline and regulated for a minimum consumption, have shown a fuel consumption as low as 0.43 lb. per b.hp-hr. with a brake mean effective pressure of about 130 lb. per sq. in.

TABLE 2—COMPARATIVE PERFORMANCE OF AIR AND WATER-COOLED ENGINES

Method of Cooling	Water	Air
Speed, r.p.m.	1,800	1,800
Rating, hp.	200	220
Cylinder Volume, cu. in.	716	787
Brake Mean Effective Pressure, lb. per sq. in.	122	123
Fuel Consumption, lb. per b. hp-hr.	0.48	0.51
Compression-Ratio	5.3 to 1	5.0 to 1

The data given show the present state of the art for small engines but, in view of the interesting work that is being carried on at McCook Field and elsewhere, I believe that before the end of 1922 air-cooled engines developing up to 50 hp. per cylinder will be showing as good, if not better, performances than water-cooled engines of the same volume.

In connection with the development of large air-cooled engines, the question of cylinder temperatures and the difference in temperature between the front and rear of the cylinder as affected by the design and the choice of material becomes of great importance. It is obvious that the side exposed to the airblast has a better chance of cooling than the side not so exposed, and it is desirable that the cylinder circumference should be equally cooled.

Progress in Engine Cooling

The great progress achieved in air-cooled development is largely due to the use of aluminum for cylinder and head construction. Not only has this material a conductivity much greater than that of cast iron or steel but, on account of its light weight, thicker sections can be used, permitting a very rapid flow of heat from points that are not exposed to a proper air flow. Its greater conductivity also allows the efficient use of cooling fins as deep as foundry practice will permit. Hot-spots are avoided in this way and more cooling surface is provided than in the case of cylinders constructed of iron or steel.

We have definite data as to the actual temperatures existing in an air-cooled cylinder of very high output, that are presented in Fig. 13. The cylinder was built by the Airco Co. in England and was tested in November 1919. It is of the roof-head type with four valves per cylinder, having a 5.5-in. bore and a 6-in. stroke. The design shown in Fig. 13 is conventionalized and does not attempt to give the true proportions of this cylinder. This engine ran at 1700 r.p.m. in a mean airblast of 87 m.p.h. and developed 42.2 b.hp., which gives a brake mean effective pressure of 138.2 lb. per sq. in., the fuel consumption varying from 0.600 to 0.565 lb. per b.hp-hr. All temperatures are in degrees fahrenheit. It will be noticed that the hottest point on the cylinder was in the head between the exhaust-valves, as would be expected, with a temperature of 516 deg. fahr. The temperature decreases at the edge of the combustion-chamber wall to 383 at the rear end to 367 deg. fahr. at the front, a difference of only 16 degrees. This small difference that exists nowhere else might be accounted for by the cooling action of the inlet-ports, but readings on each side at the same plane, not shown in Fig. 13, give a temperature of only 354 deg. fahr., or somewhat less than those at the front.

The most plausible explanation of this small temperature-difference is that the airflow around the corner of the head and combustion-chamber wall is very efficient. The maximum temperature-difference between front and rear on the aluminum head is only 94 deg. fahr., which is not serious. The temperature is less on the lower portion of the cylinder, but the difference between front and rear is much greater, with a maximum of 187 deg. fahr. This is to be expected in view of the poor conductivity of the cylinder material and the thinness of the cylinder

walls. The temperature is higher at the foot of the cylinder, which is probably due to heat transmitted from the crankcase.

Tests of the same cylinder at air speeds as low as 45 m.p.h. did not show any tendency to produce hot-spots on the rear of the cylinder. The entire temperature increased both front and rear with a smaller difference between front and rear than existed at higher air-velocities, and with a corresponding decrease of power and an increase in the fuel consumption. The brake mean effective pressure developed by this cylinder is equal to the best water-cooled practice, which may be surprising to many in view of the fact that the cylinder-wall temperatures are apparently much higher than those prevailing in water-cooled cylinders, on the assumption that these do not exceed the boiling temperature of the water that surrounds them. However, this is not the case. Tests on a Hispano-Suiza engine showed a maximum temperature on the outside of the top of the cylinder wall of 470 deg. fahr. In other words, the temperature of the cylinder walls of water and air-cooled engines are not much different.

The cylinder of the water-cooled engine is covered in part with a film of steam. Small areas of steam are formed, which are instantly swept away by the rapid flow of water and recondensed by the water that has not yet come in contact with the cylinder wall. The rapid flow of water and the formation of small areas of steam produce a state of extreme turbulence culminating at the cylinder-head. This does not produce any steam in the radiator return-pipe, provided the velocity of flow and the capacity of the water-jacket at the hottest points are

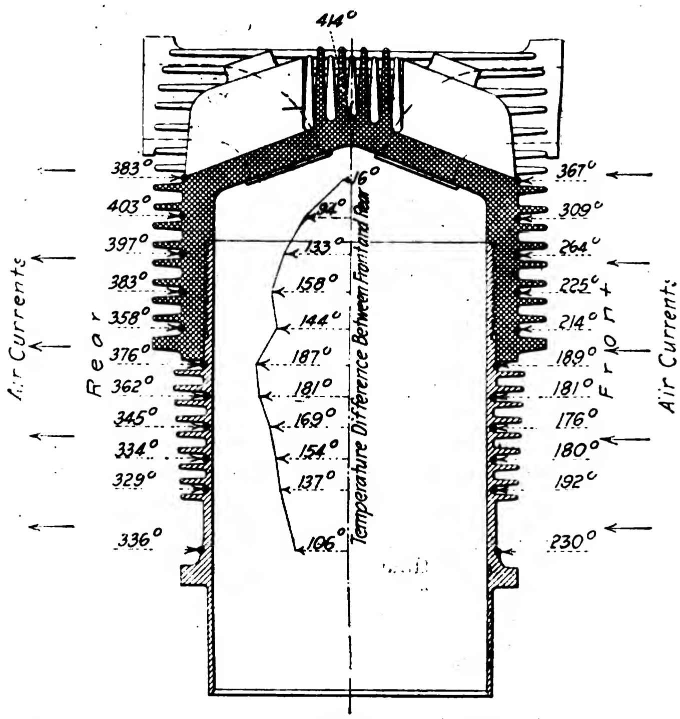


FIG. 13—TEMPERATURE DIFFERENCES IN DEGREES FAHRENHEIT BETWEEN THE FRONT AND REAR OF AN AIR-COOLED CYLINDER

adequate. The water-cooled engine is handicapped by the number of heat transfers required from one conductor to another, all of which tend to increase the ultimate temperature on the inside of the cylinder wall. The minimum number of heat transfers is three. They are (*a*) from the cylinder to the water, (*b*) from the water to the inside of the radiator core and (*c*) from the outside of the radiator to the air.

ENGINE-COOLING FACTORS

In some efficient engines like the Wright Hispano we have an additional transfer of heat, from the steel cylinder to the aluminum cylinder. In air-cooled engines the transfer is direct to the air; in the case of the combustion-chamber, and in an aluminum cylinder with steel liner, through only one additional step, it is from liner to cylinder. In the most efficient air-cooled cylinders, as shown in Figs. 11 and 13, the flow of heat to the air is the most direct that can be obtained. The water-cooled engine is handicapped also by the use of a medium that boils at 212 deg. fahr. It must be held at a certain margin of safety below this.

Let us assume in one case that the air at 60 deg. fahr. strikes a radiator having an average temperature of 180 deg., a temperature difference of 120 deg. between the air and the object to be cooled. Let us assume also that the air at 60 deg. strikes a cylinder having an average temperature of 300 deg., a difference of 240 deg. If everything were equal, air velocity, freedom of airflow, efficiency of airflow, coefficient of radiation of the two objects and the like, the cooling per unit area would be proportional to the difference in temperature of the air striking and of the air leaving the object to be cooled. In this case the cooling effect per unit for the air-cooled cylinder would be approximately 1½ to 1¾ times that of the radiator, because the cylinder temperature is nearly twice as great as the average hot-water temperature of the radiator. However, the conditions are different

(*Concluded on page* 144)

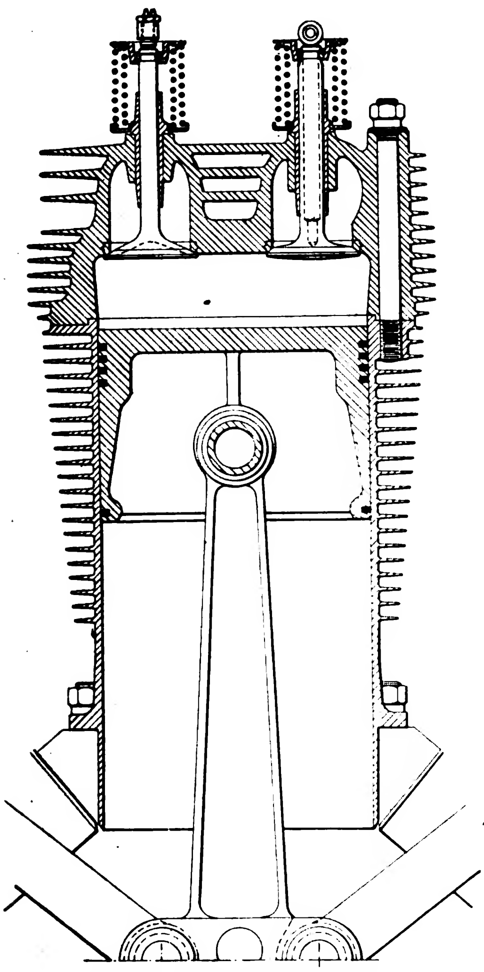


FIG. 12—CYLINDER OF THE LAWRANCE 350-HP. AIR-COOLED ENGINE

COUNCIL MEETINGS

THE 1921 Council held the last sessions of its administration on Jan. 9 and 10, the following being present: President Beecroft, First Vice-President Horning, Vice-Presidents Bachman, Crane, Johnston and VanBlerck, Past-President Vincent, Councilors Brush, Davis and Pope, Treasurer Whittelsey, C. F. Scott, O. W. Young, F. E. Watts, C. B. Segner, V. E. Clark and J. V. Whitbeck.

Forty applications for individual membership and 17 for student enrollment were approved. The following transfers in grade of membership were made: From Associate to Member, A. C. Ziebell; from Junior to Associate, A. C. Bigelow, A. R. Keagy; from Member to Service Member, I. M. Laddon; from Member to Foreign Member, David Flather, G. D. Flather and Kenske Hashimoto.

B. B. Bachman resigned as a member of the Constitution Committee and C. B. Veal was appointed in his stead.

At the request of its chairman, F. W. Davis, the Committee on Science of Truck Operation was discontinued. When the committee was organized nearly 2 years ago the intent was to study the economic adaptation of the motor vehicle and the highway, outline certain problems of research and formulate data in that connection. The committee held two meetings at which a program for development of the subject was outlined. At that time the Bureau of Public Roads started a research program on impact of motor trucks on highways, and the Highway and Highway Transport Education Committee was formed to carry on related investigations. Since that time the National Research Council has instituted a complete program of research on road resistance, tractive resistance and general economic development of highways, and work on the two first subjects is under way at the Massachusetts Institute of Technology. Dr. Dickinson, of the Research Department of the Society, is assisting in this. It was felt under the circumstances that the best thing to do was to discontinue the Committee, as stated.

Mr. Davis was appointed as an additional representative of the Society on the Engineering Division of the National Research Council.

At the session of the Council held on Jan. 10 Chairman Bachman, of the Standards Committee, reported in detail the action taken by that committee on the same day with regard to proposals of 16 of its Divisions as set forth elsewhere in this issue of THE JOURNAL. The proceedings of the Standards Committee were approved for submission to the Society in meeting assembled on Jan. 11, for consideration in the matter of referring the recommendations of the Divisions by letter ballot to the voting members of the Society for final adoption.

ORGANIZATION SESSION OF 1922 COUNCIL

The organization session of the 1922 Council was attended by President Bachman, First Vice-President Whitbeck, Vice-Presidents Clark, Young and Watts, Past-President Beecroft and Councilors Crane, Davis and Scott.

President Bachman announced the personnel of the 1922 Administrative Committees as follows:

CONSTITUTION COMMITTEE
N. B. Pope, *Chairman*
C. B. Veal W. A. Brush

FINANCE COMMITTEE
H. M. Swetland, *Chairman*
H. L. Horning C. B. Whittelsey
Russell Huff O. W. Young

HOUSE COMMITTEE
F. E. Moskovics, *Chairman*
C. F. Kettering C. B. Veal
F. S. Slocum J. V. Whitbeck

MEETINGS COMMITTEE
C. F. Scott, *Chairman*
J. R. Cautley Orrel A. Parker
M. C. Horine B. S. Pfeiffer
M. P. Rumney

MEMBERSHIP COMMITTEE
Lon R. Smith, *Chairman*
J. R. Coleman R. E. Northway
G. P. Dorris A. M. Wolf

PUBLICATION COMMITTEE
Daniel Roesch, *Chairman*
O. C. Berry D. L. Gallup
F. W. Caldwell O. B. Zimmerman

SECTIONS COMMITTEE
A. K. Brumbaugh, *Chairman*
H. R. Corse R. J. Nightingale
G. E. Goddard H. W. Slauson

President Bachman reported also the names of the members who will serve this year as Chairmen and Vice-Chairmen of the Standards Committee and its Divisions. These are listed in this issue of THE JOURNAL, as well as those named by the Council for service on the various Divisions.

The next meeting of the Council was scheduled to be held in Chicago on Jan. 31.

BRITISH AUTOMOTIVE VEHICLE STANDARDIZATION

A FURTHER step in the movement toward the standardization of automobile, motorcycle and cycle parts has been taken by the British Engineering Standards Association in the formation of seven subcommittees to undertake the following sections of the work:

(1) Nomenclature, Major C. Wheeler, *chairman*
(2) Steels, A. A. Remington, *chairman*
(3) Small Fittings, W. D. Williamson, *chairman*
(4) Electrical Fittings, E. Garton, *chairman*
(5) Shafts and Shaft Details, L. A. Legros, *chairman*
(6) Wheels, Rims and Tires, Lieut.-Col. D. J. Smith, *chairman*
(7) Cast Iron, Dr. L. Aitchison, *chairman*

A conference of the chairmen, presided over by H. C. B. Underdown, the chairman of the Sectional Committee, was held recently, at which the personnel of each of the subcommittees was very carefully gone into and provisionally agreed upon.

Before the subcommittees actually embark upon the detailed work, the various organizations concerned are being consulted to insure that the proposed personnel meets with their approval as adequately representing their respective interests. In the meantime, in order not to delay matters, technical data in regard to the specific subjects to be taken in hand immediately are being collected. — *Cooper's Vehicle Monthly* (London).

INTERCHANGEABLE MANUFACTURE

NO two things are alike. The difficulty of maintaining accuracy increases in geometric ratio with each added accurate dimension on the same piece. No machine or tool under stress can be accurate. The manufacture of interchangeable parts in quantity is a matter of percentage. Irrespective of the method used, quality is a matter of insistence.

The nearest approach to mechanical perfection that we know of is found in the Johansson gages, or was until the advent of the Hoke gages; but, within their limits, these are not interchangeable and the interferometer shows not only a variation in size but also a difference in parallelism of the same piece.

Securing one very accurate dimension on a piece is a comparatively simple matter. The ease of securing two accurate dimensions, however, depends upon the relation of the second to the first. The figures given in Table 1 are based upon practice and general impressions, but are believed to be accurate enough to justify their publication for the purpose of showing the high cost of unnecessary accuracy:

TABLE 1—RELATION BETWEEN INCREASE IN NUMBER OF DIMENSIONS AND NUMBER OF PERFECT PIECES

Number of Dimensions on One Piece	Probable Number of Perfect Pieces	Estimated Increase in Cost per Operation, per cent
1	100	0
2	90	30
3	50	75
4	15	100
5	5	200
6	0	500

In making the foregoing statements I have in mind automatic and other machines where the close-dimension work is done at one setting and in manufacturing quantities. Some will dispute the figures given in the table and declare that it is not good practice to attempt finishing pieces in the automatic, but that they should be roughed-out there and finished on a shaving lathe or elsewhere. Why should they not be finished complete when a good automatic must, in the nature of things, be, and is, as accurate as a single-purpose machine on a single accurate dimension? It is not accurate on several close ones, however, and accepted practice confirms this statement, and the reason it is not, and cannot be, accurate is the conflicting stresses.

There are many firms the engineering department of which really believe they are producing an interchangeable product of close dimensions, but their inspection and manufacturing departments could tell a different story. It is not bad workmanship or lax inspection that is responsible for their failure to produce such work, but the oft-times unnecessarily close tolerances specified on unimportant dimensions, or the insistence of close ones on several dimensions of the same piece, and it is well to stop and consider what may happen, say, to a piece of apparatus after it has been in service for some time when initially it required the centers of two shafts to be held within 0.0005 in. Interchangeable manufacture requires both relative and specific tolerance. Relative tolerance has to do with its relation to the part to which it assembles, and does not necessarily affect the tolerance of the specific dimension. Specific tolerance is that tolerance on a specific dimension required to render a particular part easy to manufacture, or to take care of the wear on tools.

Any part increases in cost with each succeeding operation, and the probability of loss should decrease in the ratio of its added value. This result should be obtained, first, by a design having in view its relation to subsequent machining operations, and, second, through the proper sequence of operations relative to their difficulty, and sufficiently divided. This leads us up to the question of registration. Automobile engine-builders cast lugs on their cylinders to insure parallelism of the bore; adding-machine and phonograph castings sometimes have bosses cast on, to take the pressure of milling or drilling operations. It is also true that sometimes we insert a pin in a drilled hole to guard against movement, but we do this only at times and usually as a matter of convenience, whereas it is a matter of necessity, and it will usually cost less to drill special holes or machine special lugs for registration and resetting than to attempt to do the work in fewer complex operations.

Nearly as important as registration is the question of clamping. One of the fundamentals laid down was that a machine under stress could not be accurate. This is just as true of a piece being machined, and unless a part is designed with its subsequent machining operations in view; unless it is supported sufficiently near its pressure centers; unless it has a three-point support with the holding or clamping pieces immediately over them, and in the case of a drill jig, independent of the part that carries the bushings, then that piece cannot be accurate. This is true of drilling always, of milling generally and of turning sometimes.

How shall tolerances be indicated; shall they be identical, independent, or overlapping; what does the law of probability and actual trial demonstrate as the probability of overlapping or identical tolerances interfering; what percentage may be expected at different parts of the tolerance, and the lessons to be learned therefrom, are subjects calling for extended treatment by themselves. The same is true of inspection, machining methods and analysis of the product.

The automatic screw-machine will, of course, always be with us, for in that we meet ideal manufacturing conditions as nearly as they can be met. But the fact that the single-spindle screw-machine persists and is even exclusive in the small-part field is still further corroboration of the price we must pay for accuracy. The question of accuracy is, of course, relative, as is the question of the rigidity of the machine; but it is important in its bearing upon the cheapness of manufacture by determining the number of cuts, retapping, reaming, grinding, and the like, that are necessary.

The law of compensation applies to mechanics as well as elsewhere in industry, and when we attempt to work to closer limits at the expense of increased operations, we must pay somehow. This is not to be considered as an argument against such a procedure, but an appeal for commonsense in interchangeable manufacture, not to make the work easier, but to reduce the cost, and the firms that are really making a good interchangeable product are those that have analyzed all the different conditions and hold the extremely accurate dimensions at a minimum. Neither should it be thought from what has been said that close dimensions may not be necessary or desirable. Some companies require them much closer than do others. It then becomes a question of whether the price received for the finished apparatus is commensurate with the close limits imposed. If not, it is a matter of increasing the tolerances so as to permit manufacture on a cheaper basis. In other words, the percentage of rejections that can be tolerated must be figured out and kept within that limit. For instance, on an apparatus costing $10, for which a liberal price is asked and received, an allowance of 50 cents per apparatus for rejections may not be excessive. If, on the other hand, the price is close, 50 cents may mean the difference between profit and loss. This is a matter of policy to be settled by the administration and not by the shop, although we very often lose sight of this fact.

In my opinion, there are no such things as close tolerances. All are relative, and we only court trouble when we try to take too many steps at once. One-half thousandth is only 5 per cent of 0.0001 and the chance of securing that accuracy in quantity in one step is about 5 per cent multiplied by the extra cost. But 0.0005 is 50 per cent of 0.0010 and the probabilities are increased in the same ratio. So we may lay it down as a truism that subdivided operations are a function of accuracy.

Analyzing our fundamentals, we find that the three ways in which interchangeable parts can be secured are by:

(1) Obtaining a percentage of good ones, with close tolerances
(2) By giving individual attention to each piece
(3) By employing liberal allowances

The first way is wasteful; the second is not manufacturing; the third means liberal unnecessary allowances and close necessary ones, with the operations divided so that each individual working upon the part has but one thing to do. Thus, on a small shaft with six diameters all ground to a 0.0005-in. limit, there should be six roughing and six finishing operations, because (*a*) different wheels may be used; (*b*) less skilled men may be employed with less chance of scrap; (*c*) the wheel will be in better condition and will not need dressing so often and the operator will not have to change his sense of proportion, "hog off" material one moment and hardly touch it the next; (*d*) the finishing operations may always be done on the most accurate machine; and (*e*) last, but not least, as a rule a single machine operator can finish more work to close dimensions in four operations than four different machinists who possess the same average ability can in one operation.—C. B. Lord before American Society of Mechanical Engineers.

AIR-COOLED ENGINE DEVELOPMENT

(*Concluded from page* 141)

in that the airflow through the radiator is restricted, due to the length of the tubes to be traversed, the inefficient shape of the entrance and outlet of each tube and the restriction back of the radiator which is often very great. In the case of the cylinder, the fins offer less resistance to the air because they are comparatively shallow and tapered, and the propeller pulsations produce a condition of turbulence back of the cylinder that carries away the air located behind it. It will be seen that, although it is not possible to arrive at any definite figures, the cooling of the cylinder per square foot of area is much more efficient than that of the radiator per square foot of area; hence the need for much less radiating surface to produce the same result.

At present data are not available to determine the comparative resistance of the two types installed in similar airplanes, but it is hoped that the necessary information will become available during this year. However, it is fair to state that, since the use of radial air-cooled engines is in its infancy, much better methods of installing and cowling these engines will be developed. An example of work along these lines is the wind-tunnel test of a British airplane, the Westland Weasel, a small pursuit plane equipped with an A. B. C. Dragonfly engine having a diameter of nearly 49 in. The tests were made at a velocity of 100 ft. per sec. The resistance of the fuselage without the cylinders and with the cylinder openings faired is 0.270 lb.; with the cylinders in place it is 0.616 and with crusader cowls 0.444 lb.

The crusader cowl is a form of cowl attached to the head of each cylinder and somewhat resembling a helmet of the type having a small visor and a curved-up portion at the rear for the protection of the neck. The fuselage resistance is increased 128 per cent by the addition of the cylinders, but is increased only 65 per cent with the use of the cowls. The fuselage without cylinders is nothing but a round-section streamlined body and it is reasonable to believe that the addition of any water-cooled engine of equal power, with radiators and the like, would have caused considerable increase in the amount of the resistance to the passage of the aircraft through the air.

Another possible method of installing air-cooled engines is that of completely enclosing the engine in a cowl. The Smith engine, developed some years ago, was completely enclosed and provided for cooling the cylinders not only at the front but at the back, taking the air from an opening around the propeller-hub. When tested at McCook Field, an engine of this type showed very good cooling. On airplanes other than those of the pursuit type, in which the engine is out of all proportion to the size of the plane, such an installation should be possible and enable us to obtain the low fuselage resistance of the water-cooled-engine ship, with the admitted advantages of the air-cooled engine.

THOMPSON AUTORIFLE

(*Concluded from page* 134)

the advantages of semi-automatic fire in battle are not fully conceded by all military experts. Rapidity of fire, however, has been one of the most important considerations affecting the design of small arms since time immemorial.

Probably no tradition of our Army is cherished so dearly as the proverbial markmanship of the American soldier. This tradition has been fostered by most careful training methods to such an extent that it is seldom, if ever, that an American rifle team is defeated in international competition. The degree of proficiency obtained by American Army training methods with the enlarged forces involved in the war, was certainly successful in that the American soldier, as a rule, was superior in marksmanship to his allied comrades in arms, and equal to at least the best trained enemy forces. With the advances made during the last century in the application of the principle of replacing man-power by machine-power, the advent of automatic fire in replacing hand-loaded fire cannot be far distant. If, to hold a position that is opposed by isolated units of automatic fire, it is necessary to concentrate thickly marksmen using hand-loaded weapons for the purpose of maintaining fire superiority, many believe our world-war experience has shown us that the price is paid in blood.

ADVANTAGES OF AUTOMATIC-RIFLE FIRING

At the critical moment that occurs in every battle, other things being equal, the side that brings the preponderance of lead to bear will be victorious. If, by the adoption of a semi-automatic shoulder rifle it is made possible for the soldier to deliver at the critical moment 40 aimed shots per minute against the soldier who with his hand-loaded weapon fires 20, the result can be surmised.

However, in the past, the semi-automatic shoulder rifle weighing under 10 lb. and firing the high-powered military cartridge has not only proved unreliable in action, but totally unable to endure the many rigors required of it. If the self-acting lock is an answer to the many problems involved, the prestige of the American gun engineer will move one step above the stage to which it has been raised throughout each decade by such inventors as Hall, Maynard, Henry, Sharp, Rider, Lewis and Browning.—Col. H. E. Hartney in *Army Ordnance*.

ACTIVITIES OF THE SECTIONS

Secretaries of the Sections

BUFFALO SECTION—C. A. Criqui, Chairman, Sterling Engine Co., Buffalo
CLEVELAND SECTION—E. W. Weaver, 5103 Euclid Avenue, Cleveland
DAYTON SECTION—R. B. May, Dayton Engineering Laboratories Co., Dayton, Ohio
DETROIT SECTION—B. Brede, assistant secretary, 1361 Book Building, Detroit
INDIANA SECTION—B. F. Kelly, Weidely Motors Co., Indianapolis
METROPOLITAN SECTION—F. E. McKone, 347 Madison Avenue, New York City
MID-WEST SECTION—T. Milton, 140 South Dearborn Street, Chicago
MINNEAPOLIS SECTION—C. T. Stevens, Reinhard Brothers Co., Minneapolis
NEW ENGLAND SECTION—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston
PENNSYLVANIA SECTION—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
WASHINGTON SECTION—B. R. Newcomb, 211 Victor Building, City of Washington

AT the invitation of the Burlington, Vt., Chamber of Commerce, President Beecroft gave an address on commercial aviation before that body on Jan. 4.

At the Washington Section meeting on Jan. 6 an account of the remarkable regularity of the Air Mail Service was given. The speakers were Second Assistant Postmaster General E. H. Shaughnessy, C. L. Egge, general superintendent of the Air Mail Service, and Major H. W. Harms.

The Metropolitan Section joined the local section of the American Society of Mechanical Engineers in a meeting on Jan. 17, at the Engineering Societies Building. P. L. Battey gave a paper on the design of a plant for the production of automobiles on the progressive-assembly plan.

The Buffalo Section on Jan. 17 heard with interest Prof. F. O. Ellenwood talk on Pneumatic Truck Tire Temperatures. He had spent some months in devising instruments for measuring these temperatures to obtain data on the origin and radiation of heat in tires. On Jan. 24 Major L. B. Lent, formerly general superintendent of the Air Mail Service, gave one of the best papers of the entire aviation series before the members of the Buffalo Section. His cost analysis of the Air Mail Service was of extreme interest.

C. H. Norton gave a paper on grinding machines and processes before the New England Section at the Boston Engineers Club on Jan. 20.

R. W. Daniels spoke on Duralumin at the Cleveland Section meeting on Jan. 20. This remarkable alloy is of practical interest at this time because of its growing use in the aviation industry.

COMING AVIATION SESSIONS

It is the intention of the members of the Society located in Cincinnati to hold an aviation meeting early in February, probably on Feb. 2. Invitations will be issued to the local section of the American Society of Mechanical Engineers, the Chamber of Commerce and other organizations to join with the members of the Society in this meeting.

San Francisco, while not having a regularly constituted Section of the Society, has a live local committee, headed by Frank B. Drake, which has arranged some interesting meetings for the members of the Society in that territory. This committee has planned to have a speaker on commercial aviation and to show the moving pictures of the bombing of ex-German war vessels by aircraft at a meeting on Feb. 16. It is expected that the Los Angeles and the Seattle groups will hold similar meetings during the month of February.

ANNUAL REPORT OF THE SECTIONS COMMITTEE

At the Summer Meeting of the Society held at West Baden last May the Sections Committee made the proposal that a strong effort be made by the Program Committee of each Section to arrange its schedule of meetings for the ensuing year well in advance. It was believed that with proper attention the dates of meetings could be fixed for the entire year and that the full program of subjects to be treated could be outlined at

Schedule of Sections Meetings

FEBRUARY

3—WASHINGTON SECTION
3—MID-WEST SECTION—Modern Ideas About the Nature of Matter — Address by Prof. H. B. Lemon
8—MINNEAPOLIS SECTION — Road-Building Machinery and Engineering
10—NEW ENGLAND SECTION — Isolated Lighting Plant Meeting at Boston or Worcester—Paper by Mr. Wilkins, of the H. C. Dodge Co.
16—SAN FRANCISCO—Aviation Meeting
21—BUFFALO SECTION—Resilient Wheels—Paper by A. C. Vauclain
21—METROPOLITAN SECTION—Motorboat Meeting
23—PENNSYLVANIA SECTION — Current Business Conditions and the Engineer's Place in Commercial Development
24—DETROIT SECTION—Light-Weight Pistons and Piston-Rings—Paper by F. Jehle and F. Jardine

MARCH

7—DAYTON SECTION — Recent Developments in Water-Cooling—Paper by L. L. Snow
10—NEW ENGLAND SECTION—Business Aspects of the Automotive Industry
16—METROPOLITAN SECTION
21—BUFFALO SECTION—Electric Wiring Systems —Paper by W. S. Haggott
23—PENNSYLVANIA SECTION—Batteries and Electrical Equipment. Also paper by J. M. Teasdale
24—DETROIT SECTION
31—MID-WEST SECTION — Various Commercial Fuels and Their Relative Characteristics

the beginning of the season. It was thought also that in a great many cases it would be possible to schedule the desired speakers a number of months in advance of the presentation of their papers. The Sections Committee believed that such activity on the part of the Program Committees would result in better papers and larger audiences.

In the Sections that followed this suggested procedure the results have been highly satisfactory. By notifying the Section members well in advance of the dates and subjects of meetings throughout the year, a larger attendance has been secured, and by allowing speakers sufficient time for preparation better papers have been presented. It is recommended that all of the Sections fix the dates, select the subjects and, so far as possible, arrange for the speakers at once for the rest of their season, if this has not already been done.

At the Sections luncheon at West Baden the suggestion was made that extension meetings be held from time to time in cities where no Sections are established. Another idea was that one month of the year be devoted to the special consideration of the status of Commercial Aviation. Accordingly, Aviation meetings have been held or will be held shortly at Boston, Buffalo, Cleveland, Detroit, Indianapolis, New York City, Chicago, Philadelphia, City of Washington, St. Louis, Burlington, Vt., San Francisco, Los Angeles, and Seattle. Speakers for these meetings were selected not only from the membership of the Society but from the personnel of various organizations engaged in aviation, including the War, Navy and Post-Office Departments. A large amount of information was brought out showing the progress that has been made recently in commercial aviation, and consideration was given to the retarding influences that are now acting against more rapid development in this field. The attendance at the meetings was in general over twice the normal attendance at Sections Meetings. There was a considerable amount of newspaper publicity in connection with them. It is believed that the meetings were of real assistance to the aviation industry in acquainting the public with the truth of the present situation as it affects that particular branch of the automotive industry.

In a number of the cities at which Sections of the Society are located discussion has been had as to the desirability of some sort of affiliation between sections and the respective local engineering societies or clubs. The Sections Committee has kept in touch with these developments, considering each case on its merits, and recommended in some instances a form of affiliation.

The Committee feels that the Sections have cooperated with it in an admirable manner, and trusts that they will maintain close contact, through the office of the Society, with the 1922 Sections Committee.—(Signed) Hugh R. Corse, Chairman of the Sections Committee.

OBITUARY

Clarence E. Rogers, chief engineer of the Huffman Bros. Motor Co., died at his home in Elkhart, Ind., Dec. 18, 1921, aged 36 years. He was born in St. Joseph County, Ind., on Sept. 23, 1885, and was graduated from the local grammar school in 1901. His other education was a correspondence course in mechanical engineering that he completed in 1905.

Mr. Rogers' business experience began in November, 1905, with his entrance into the service of the Dodge Mfg. Co., Mishawaka, Ind., as a machine operator, where he remained until March, 1907, when he became associated with the Amplex Motor Car Co., also of Mishawaka, as a tracer and detailer on automobile work. In October, 1909, he accepted a position with the Advance-Rumely Co. at Laporte, Ind., where he was engaged in detail and layout work on Oil Pull combustion engines for approximately 2 years. He subsequently accepted a position as chief draftsman with the Wire Specialty Co., South Bend, Ind., and was engaged on special wire forming machinery, afterward becoming foreman of the experimental department, where he designed wire and bending machines. From April, 1913, to July, 1915, Mr. Rogers was assistant chief draftsman with the Western Electric Co. at Chicago, where he developed special equipment for telephone exchanges.

With the exception of 1 year, Mr. Rogers' connections since January, 1916, have been with the automotive industry in the vicinity of Elkhart, Ind. He was chief draftsman and assistant production engineer with the Sun Motor Car Co. for approximately 15 months when he entered the service of the Crow Motor Car Co. as chief inspector. From June to September of 1917 he was engaged as a tool and jig designer by the Foster Machine Co. In September, 1917, Mr. Rogers was compelled to relinquish this position on account of poor health and for a year was a salesman for the Aluminum Cooking Utensil Co. of New Kensington, Pa. In October, 1918, he was appointed chief engineer of the Huffman Bros. Motor Co., a position that he held continuously until the time of his death. Mr. Rogers was elected to Member grade in the Society, Dec. 10, 1919. His widow survives him.

THE WIND-TUNNEL

The wind-tunnel, established for the purpose of aeronautical instruction, opens a wide field for scientific research. The fundamental laws of fluid dynamics are still in the elementary stage and require empirical research of a highly specialized nature.

There are many applications of wind-tunnel work outside the confinements of mechanical flight. The Government wind-tunnel sections receive inquiries of divers nature from blower companies, ventilation engineers, fan manufacturers, windmill designers and designers of wind-bracing; in fact from all the older branches of engineering wherein the phenomena of fluid dynamics play a part. Examples are: tests on the wind resistance of roofs and buildings, the windage of battleships, the heat conduction of radiators due to air-flow, the calibration of flowmeters, the action of ventilating apparatus, the design of blowers and fans, the nature of the meteorological movements of the wind, the nature of the flow of gases in pipes and the question of noise propagation in the air by ventilation apparatus.

Without the wind-tunnel there is no way to find out precisely what the air does in any given application. Suppose, for example, a blower manufacturer suspects he can improve the efficiency of his product, perhaps by changing the shape of the impeller vanes. In the past he availed himself of the cut-and-try method, making up one after another full-sized impeller wheel until satisfactory results were obtained. Today he can go to the wind-tunnel, secure tests on small models of isolated blades, and from the coefficients thus determined design his machine with full assurance of success. Wind-tunnel coefficients have been found to apply with great success to the case of rotary blowers.—E. N. Fales and F. W. Caldwell in *Aerial Age Weekly*.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Dec. 10, 1921, and Jan. 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ARROW, PERCY JOHN (A) technical salesman, Associated Equipment Co., Ltd., Walthamstow, London, E. 17, (mail) 12a Clarendon Road, Putney, *London, S. W. 15, England.*

BACKUS, HAROLD A. (M) chief inspector and metallurgist, Gallaudet Aircraft Corporation, *East Greenwich, R. I.*

BAUMAN, JOHN NEVIN (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 1109 Prospect Street.

BOCK, OSCAR LOUIS (E S) Iowa State College, *Ames, Iowa,* (mail) 2116 Lincoln Way.

BORRESON, HARRY (A) foreman of practical test laboratory, American Bosch Magneto Corporation, 520 North Main Street, *Springfield, Mass.*

CARLSON, R. E. (S M) chief of tank section, tank, tractor and trailer division, Chief of Ordnance, *City of Washington.*

CLINE, EARL E. (M) Ernest Holmes Co., *Chattanooga, Tenn.*, (mail) 867 McCallie Avenue.

COBURN, H. H. (M) Wellesley School Department, (mail) 320 Washington Street, *Wellesley Hills, Mass.*

DIEDERICHS, H. (M) director of school of engineering, Cornell University, *Ithaca, N. Y.*

EASTMAN, EDWARD H. (E S) student, Iowa State College, *Ames, Iowa,* (mail) 203 Welch Avenue.

FISHER, CARL HERBERT (A) assistant service manager, General Motors, Ltd., London, S. W. 7, (mail) 24 Minet Avenue, *Harlesden, London, N. W. 10.*

FITZPATRICK, JAMES R. (M) secretary, Haskelite Mfg. Corporation, 133 West Washington Street, *Chicago.*

FLORO, MARTINIANO (E S) student, University of Illinois, Urbana, Ill., (mail) P. O. Box 563, Station A., *Champaign, Ill.*

GANSTER, LOUIS T. (A) president and secretary, Berks Auto-Ignition Co., 514 Cherry Street, *Reading, Pa.*

GLENN, JOHN W. (A) president and general manager, Glenmore Co., Inc., 169 Delaware Avenue, *Buffalo.*

GOOD, CHARLES WINFRED (M) instructor, University of Michigan, *Ann Arbor, Mich.*, (mail) 1014 Cornwell Place.

HART, RICHARD LECKLIDER (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 408 East Washington Street.

HOWELL, K. J. (J) 802 Ocean Avenue, *New London, Conn.*

JOHNSON, CARL A. (M) sales engineer, Hyatt Roller Bearing Co., Chicago, (mail) R. F. D. 9, Box 153, *Muncie, Ind.*

KIRKPATRICK, WILLIAM J. (A) assistant service manager, A. Schrader's Son, Inc., *Brooklyn, N. Y.*, (mail) 470 Vanderbilt Avenue.

LA HATTE, MILNER T. (A) manager and engineer, Southern division, Selden Truck Corporation, Rochester, N. Y., (mail) 322 Peachtree Street, *Atlanta, Ga.*

LOVEJOY, RALPH M. (A) president, Lovejoy Mfg. Co., 39 Brighton Avenue, *Boston.*

McLERIE, A. G. (A) officers' mess, Canadian Air Force, *Camp Borden, Ont., Canada.*

MILLER, HOWARD A. (J) junior partner, Automotive Service Co., 295 Plymouth Avenue, South Rochester, N. Y.

PARKS, CHARLES (A) president and sales manager, Parks-Campbell-Finley Motor Co., *Oklahoma City, Okla.*, (mail) 2410 Classen Boulevard.

PARR, C. H. (M) engineer, Hart-Parr Co., *Charles City, Iowa,* (mail) 100 Hulin Street.

RAYCROFT, LOUIS B. F. (A) manager, Boston service depot, Electric Storage Battery Co., Philadelphia, (mail) 720 Beacon Street, Boston.

RIPLEY, JOSEPH P. (M) general manager, Brewster & Co., Queens Plaza, *Long Island City, N. Y.*

ROEMER, ARTHUR (M) designer, Hupp Motor Car Corporation, *Detroit,* (mail) 2579 Field Avenue.

SACKETT, A. H. (A) service manager, Elgin Motor Car Corporation, *Chicago,* (mail) 5221 Drexel Avenue.

SCHILLING, C. A. (A) chief inspector, Yuba Mfg. Co., *Benicia, Cal.*, (mail) P. O. Box 856.

SEISS, GEORGE J. (A) president, chief designer and estimator, Seiss Mfg. Co., 3835 Alexis Avenue, *Toledo.*

SHARPE, C. H. F. (J) care of Rev. H. F. Sharpe, *Claremont P. O., Jamaica, British West Indies.*

SHARON PRESSED STEEL Co., (Aff) *Sharon, Pa.*
Representatives:
Brunst, R. O., chief draftsman.
Reid, R. B., sales manager.
Zellmann, H. W., general superintendent.

SPRIGGS, CECIL T. (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 1995 15th Street.

STALNAKER, R. H. (A) assistant highway engineer, California Highway Commission, Forum Building, *Sacramento, Cal.*

STROEBEL, GEORGE ARTHUR (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 145 Eighth Street.

SVENSON, CHARLES W. (A) mechanical superintendent, Corbin Screw Corporation, *New Britain, Conn.*, (mail) 41 Park Terrace.

TERHUNE, JOHN E. (A) superintendent, Cox Brass Mfg. Co., *Albany, N. Y.*, (mail) 86 North Allen Street.

WILLIAMSON, JOHN EARL (E S) student in mechanical engineering, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 2242 13th Street.

YOUNG, RAYMOND WILLIAM (E S) student, Yale University, *New Haven, Conn.*, (mail) Box 1294, Yale University.

WILLIS, REX C. (A) 734 Larkin Street, *San Francisco.*

Applicants *for* Membership

The applications for membership received between Dec. 24, 1921 and Jan. 16, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed that the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ADDAMS, CHARLES D., sales engineer, Bearings Co. of America, *Lancaster, Pa.*

BAYBUTT, JOHN W., draftsman, Selden Truck Corporation, *Rochester, N. Y.*

BUCK, ARTHUR V., repair shop foreman, Hahn Motor Truck Co., *Hamburg, Pa.*

BUGGIE, HORACE H., vice-president and general manager, Dura Mechanical Hardware Co., *Toledo.*

BUS TRANSPORTATION, 10th Avenue at 36th Street, *New York City.* (Affiliate membership).

CLARKE, JAMES RUSSELL, president, American LaFrance Fire Engine Co., *New York City.*

CLARKE, JAMES RUSSELL, JR., student, Cornell University, *Ithaca, N. Y.*

COOPER, M. S., vice-president, Asbestos & Rubber Works of America, Inc., *New York City.*

CRAIG, NORMAN, president and general manager, Light Alloys Co., *Cleveland.*

DAVIS, WILLIAM N., body engineer, Cadillac Motor Car Co., *Detroit.*

DUN, FAY A., instructor, Ohio State University, *Columbus, Ohio.*

EDDISON, W. BARTON, consulting engineer, 366 Madison Avenue, *New York City.*

GALLAUDET, EDSON F., chief engineer and chairman of board of directors, Gallaudet Aircraft Corporation, *East Greenwich, R. I.*

GOODWIN, G. J., instructor, Northeastern College, *Boston.*

GOUDY, CARL F., instructor, Pratt Institute, *Brooklyn, N. Y.*

HARDING, JOHN, JR., aviation mechanician, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

HARPER, D. ROBERTS, 3RD, physicist, Bureau of Standards, *City of Washington.*

HOPKINS, PETER A., mechanical engineer, Penn Spring Works, *Baldwinsville, N. Y.*

JOHNSON, ANDREW F., instructor, Correspondence School for Automobile Body-Makers, *Gray, Me.*

JOHNSON, WILLIAM G., engineer, Commonwealth Motors Co., *Joliet, Ill.*

JOHNSTON, WILLIAM STANLEY, engineer, Motor Wheel Corporation, *Lansing, Mich.*

KEITH, ROBERT R., superintendent, International Harvester Co., *Chicago.*

KEPLER, ARTHUR R., sales engineer, Stewart-Warner Speedometer Corporation, *Chicago.*

LINDT, MAJOR JOHN H., United States Military Academy, *West Point, N. Y.*

MADELUNG, GEORG H., airplane designer, Glenn L. Martin Co., *Cleveland.*

MARVIN, CHARLES FREDERICK, student, Ohio State University, *Columbus, Ohio.*

NIGG, H. N., vice-president and general manager, Detroit Bevel Gear Co., *Detroit*

NUTT, ARTHUR, chief engine engineer, Curtis Aero & Motor Corporation, *Garden City, N. Y.*

OLEN, WALTER A., president and manager, Four Wheel Drive Auto Co., *Clintonville, Wis.*

OSBORN, GEORGE W., superintendent bearing department, Hoyt Metal Co., *Granite City, Ill.*

PRAY, MAYNARD, assistant to manufacturing executive, Holt Mfg. Co., *Peoria, Ill.*

RIEGER, NELSON MILES, student, Ohio State University, *Columbus, Ohio.*

SCHLAFMAN, CLIFFORD JACOB, student, Ohio State University, *Columbus, Ohio.*

SHILLITO, W. H., vice-president and purchasing agent, Bessemer Motor Truck Co., *Grove City, Pa.*

SIKOROVSKY, F. J., division superintendent, American Car & Foundry Co., *Chicago.*

STEVENS, S. B., *Rome, N. Y.*

SYKES, GEORGE, general manager, Van Blerck Motor Co., *Monroe, Mich.*

TILDEN, MERRILL W., president, Falls Motors Corporation, *Sheboygan Falls, Wis.*

TOUR, SAM, metallurgist, Doehler Die-Casting Co., *Brooklyn, N. Y.*

TREE, RUSSELL M., technical supervisor, Kenosha branch, American Brass Co., *Kenosha, Wis.*

URBAN, WILLIAM C., chief engineer, Hoyt Metal Co., *Granite City, Ill.*

WALKER, K. G., general manager, Thermal Engineering Corporation, *New York City.*

WITHEROW STEEL CO., *Pittsburgh.* (Affiliate Membership).

THE

JOURNAL
OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Published by the Society of Automotive Engineers, Inc., 29 *W. 39th St., New York*

Issued monthly, 50 cents a number, $5 a year; foreign $6 a year; to members, 25 cents a number, $2.50 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1913.

B. B. Bachman, *President* | Coker F. Clarkson, *Secretary* | C. B. Whittelsey, *Treasurer*

Vol. X | MARCH, 1922 | No. 3

INDEX

Activities of the Sections	223
Announcement of Summer Meeting	211
Applicants for Membership and Applicants Qualified	227
Chicago and Minneapolis Meetings	163
Commercial-Body Supply and Service — C M Manly and C B Veal	179
Current Standardization Work	224
Developing a Method for Testing Brake-Linings — S von Ammon	153
Distribution of Income from Production	226
Drop-Forging Practice — J H Nelson	207
Highway Transportation as It Affects the Automotive Engineer — E W Templin	212
How the Engineer Can Help Business — R H Grant	149
Internal-Combustion Engine Fuels — C A Norman	187
Manifold Vaporization and Exhaust-Gas Temperatures — O C Berry and C S Kegerreis	171
Past, Present and Future of the Motor-Omnibus — Walter Jackson	200
Personal Notes of the Members	Adv Section 2
Recent Aircraft Engine Developments — C Fayette Taylor	204
Relation Between Fluid Friction and Transmission Efficiency — Neil MacCoull	193
Relation of the Tractor to the Farm Implement —G Douglas Jones	177
S A E Standards Exhibit at Minneapolis Tractor Show	225
Spectroscopic Investigation of Internal Combustion — Thomas Midgley, Jr and W K Gilkey	218
Super-Machine-Gun	220
Men Available	Adv Section 44
Positions Available	Adv Section 54

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. X March, 1922 No. 3

How the Engineer Can Help Business[1]

By R. H. Grant[2]

It would be of little avail for me to tell what the engineer can do to help business as it stands today unless we agree on how business stands today. I believe that we can look forward into the future with optimism. Let us examine the case and see whether we have any grounds for coming to that conclusion. To do that we must go back to 1914. Then this Country was having a hard time to sell goods. At that time I was sales-manager of the National Cash Register Co. We had a powerful selling force but were having a difficult time to dispose of our product in the usual quantities because the retail merchants to whom we sold were in trouble. A new tariff law had just become effective and the Country was being flooded with goods from abroad. We could not keep our own factories running. In October 1913 we began to find a sales resistance such as we had not found since 1907.

In 1915 the condition changed completely. The countries of Europe were engaged in war and stopped sending goods here. An artificial tariff wall was set up, the strongest we had ever known. There was the greatest demand we had ever known for our goods and we began sending them across the ocean as fast as the ships would carry them. On top of that came higher wages, and larger purchasing power of domestic consumers. It was a matter of whether we could fill the orders. We were in the strongest sellers' market we had ever seen. Our purchasing agents became the salesmen and the salesmen took on the attitude of the former purchasing agents. It was a question of, When can you give it to us? Can you not give it to us a little quicker? It was a case of taking anything; it was the promoter's time, the promoter's delight; anything would go across; men thronged into business who could not have met the competition that existed prior to 1915. The numbers of people now in certain industries are double what they used to be. In addition there was a tremendous increase in our production facilities. Machine-tools were produced in large quantities, our shops were filled up with them and the floor-space was increased. On the farms we put new areas under cultivation; we expanded in agriculture just as fast as in manufacture.

[1] Address delivered at the Chicago Service Dinner of the Society of Automotive Engineers, Inc., Feb. 1, 1922.

[2] General manager, Dayton Engineering Laboratories Co., Dayton, Ohio.

Post-Armistice Business

The Armistice was signed. It should have been evident to all of us that conditions would change. We slowed up, we watched and waited, and we got a little different condition for 2 or 3 months. Then suddenly there was more business than we had before. In analyzing the situation we had forgotten that in filling the demands of Europe we had been holding back the filling of domestic orders. We took care of that home consumption, and economic principles began to act. We all planned for a big fall business in 1920. We pyramided our orders for raw material and parts. We were figuring that our shipments in September, October, November and December would be at least 50 per cent greater than they were in the fall before, which was a wonderful season, but those who could read saw signs as far back as May of little hitches here and there in the sales. Little quivers in the sales curve began in June and July.

Big Inventories Maintained

Did we take any heed? Did we start canceling orders for material? As a rule, no. A few of the wise ones did, but they were few and far between. Then when that wonderful business that was to come in the fall dropped down to an off-season volume, did those pyramided orders drop down? They surely did not; they piled up until our receiving-rooms were filled from floor to ceiling. What happened? We had inventories large enough to take care of twice the volume of business that we expected to get.

We went into January of last year with those big inventories. We had big stocks of goods out in the field in the dealers' hands. Our order records were fairly good in some instances, but an order was not a shipment, and while Mr. Distributor and Mr. Dealer and Mr. Salesman and Mr. Merchant were absorbing the excess stock that we had always carried as a floating reserve in the past, we were not making any shipments from the factory. When I say "we," I mean everybody.

The outlook was rather gloomy. What did we do about it? We got just as busy as we could to increase sales activity. Most of us were not in shape at that time to do anything with the prices. We had big fixed-charges to take care of. We had expanded; our properties were bigger; maybe we had some borrowed money. We cut our overhead expense and put our operations on

the safest and soundest basis possible, taking every means to decrease inventories. That entailed hardship and loss. It was one of the most difficult things that the managers of business in this Country ever had to do. But it was a sounder, saner thing than we did in the previous fall, when we hoped against hope that a tremendous volume of sales would come.

Requisite Conditions Today

Today the plant that cannot sell less product before it comes to the turning-point between profit and loss is in a very bad way. It should be able to make a profit on the sale of less goods than it could 1 year ago; otherwise it has not been properly liquidated. If it has not been properly liquidated, it certainly should make the dust fly to get into that condition.

Goods are beginning to come from Europe. At Christmas time we were flooded with German cutlery and small articles that do not require big tooling, the things that the Germans are expert in making; and more and more goods, regardless of any tariff that is put up, are bound to stream into this Couutry. Moreover, there is no great demand abroad for our manufactured products, and the exchange rates are such that it is most difficult to attempt to sell goods even in the countries that do have a demand for our goods. We who are in the manufacturing business must first stimulate home consumption and, if we have larger plants than the amount of business we can do justifies, perhaps we will have to close up a couple of buildings or shut off a portion of the factory, putting ourselves into such shape that with the amount of sales expectation we have we can go into black figures. Getting onto that kind of a basis is one of the biggest achievements in doing business today.

Basis of Optimism

Now as to that optimism business. We have been through a period of liquidation. It started in the basic materials, such as wool, leather, cotton and copper, before it hit the articles that we sell. It has been going on and on until in the case of a lot of our basic materials we are down practically to prewar prices. In connection with the consumption abroad of our products, one cause for great optimism exists; our shipments of basic raw materials to Europe have fallen off very little in quantity. Only 6 per cent less grain went to Europe in the first 9 months of 1921 than in the first 9 months of 1920. There was a falling off of values, to be sure. In other words, Europe still has an enormous purchasing power for those raw materials that she absolutely has to have. If prosperous conditions are to be restored in this Country, the farmer must resume buying goods. The farmer will come back to buying goods for the reason that Europe will take a great part of the surplus he produces. There is every indication that she will take just as much this year as she did last year. If Russia were shipping wheat to the rest of the world, we would have a different story to tell. Argentina cannot supply all the needs. We can compete with her. Our surplus farm products, except in the case of corn, will be well taken care of by the demands from Europe. That is a most encouraging sign.

If I thought that liquidation is to continue to the ultimate limit, I would say it would be 2 or 3 years before we could get into the same optimistic frame of mind that we can get into now if we understand the situation. In other words, if we had to wait until Mr. Retailer sells his goods on a proportional basis to Mr. Wholesaler, and until the wage-earner gets the same wages that he got before the war, we would be waiting for liquidation to be completed entirely, and would have a long, hard journey ahead of us. We cannot do that, it seems to me; a barrier is set up by the inability of the retailer, with his high rents and expenses, to get down to the wholesaler's level. In addition, wages cannot come down until the price of living comes down.

I think that within a few months we shall take the path of least resistance. Wholesale prices are showing an upward tendency. They started some weeks ago; they tumbled back again but will make another start. We will do business again in fair volume, not on a boom-time basis. Prices in certain lines that have not been liquidated will continue to come down. We were on the tenth story during the war. We have come down to about the fourth story. We will stay there for a while and do a fair volume of business for 15 or 16 months. Then we will have another slowing-up period and go down to the third story. Finally, one of these days, we will get down to the ground. That is what has happened in the past in similar situations. Liquidation has never run to the point where everybody was evened up before business was resumed. The best authorities agree on that. That is why I am optimistic for the coming year. We should, however, be safe and sane optimists. We should not expect that by some miracle or channel that we cannot reason out or in some mysterious manner all of a sudden a great volume of sales will enable us to indulge in the extravagances we have been indulging in.

Factory Team-Play

This is a time when the head of a company ought to be surrounded by at least four good business-men working hand-in-glove with him. In the past we have been too highly specialized in our four departments. My idea of running a business is that there should be a head, a financial man, a manufacturing man, an engineer and a salesman. I believe that in our past operations great extravagances have often been set up because we had four specialists all working to their own ends and disregarding the interests of the other fellows. We have come to a point where those four men should know something about the others' business. They should cooperate and do the best team-work that is in them.

There have been too many companies in which the treasurer was the only business-man and everybody else was getting all he could for his department, thinking he was serving the business in a glorified fashion, regardless of what he was doing to the profit and loss statement. We must not permit that in these times. We cannot afford to do so. We must see that every one of these men understands that the reason we are in business is, not to boost the sales department, not to make the engineering department the only well-organized department, not to have mahogany furniture, but to make money through selling a sound and good product that does good to humanity. In the past too few of us have felt that this was the prime purpose.

The Business Budget

To meet a reasonable volume of business, that may still be too small for an over-expanded plant, let us all cooperate as business men, lay out our budget, find out what sales we must have against that budget, and then get them. I believe that in these days every business should be budgeted. The comptroller of every company should have passed in to him a statement fifteen days before the month in which the money will be spent, showing just exactly what every department-head will spend. That should be gone over and no man should be permitted to

spend money until the budget items have been questioned, considered and approved by the comptroller. No man running a business, when a fellow comes up to him and says, "I think we need a new floor in here," should reply, "Yes, go on and put it in." How does he know that the treasurer has the money to put that floor in during that particular month? The budget should be planned, the man from the receiving department should indicate how much money is to come in, and the treasurer should go over the proposition and say, "All right, we can afford to do that and we cannot afford to do this." If they cannot do it this month, let them put it off until a month when they can. The four men specified, operating together, should live within the budget. If you are living within a budget, you can pretty well bank on it that at the end of the year you are coming out all right. There has been too much tendency to let the sales-manager steam ahead with a heavy advertising campaign involving expenses unrelated to anything else. Have we not sometimes had the chief engineer working on a model that might be good in 1926? What good will it do us in 1922? Is not the manufacturing man sometimes switching all his machinery around to get a better routing when he could save considerable money by leaving it as it was for the amount of business we happen to be doing? Can we not help each other tremendously by coordinating all of those things and welding them into one useful business policy that the treasurer finally says can be handled? That is a thing we ought to look into very carefully.

Selecting Sales Territory

I am inclined to believe that in the selling end of the business matters will be difficult. Sales were difficult in 1911 and the 2 following years, but we got a good volume. We were pretty keen as salesmen in those days; we were pretty hard; we were well exercised. We must admit we got out of practice during the war; things came too easy; and we are pretty much out of practice yet. Some men absolutely did not try to sell anything; they do not know now whether they can sell; they are just overcome and are lying on their franchise. Other men were of sterner stuff; they met the conditions and got results.

What should we be doing in the sales end of the business? First, the chief engineer ought to know something about the selling, as should the treasurer and the whole team working together. The management should analyze what must be done. A great mistake that all of us can make this year is trying to do impossible things in selling goods. I can take you to sections of the Country where, in the case of our particular business, if you spent $100,000 in sales overhead, you would come out at the end of the year with about as many lighting plants as two good-sized fellows could sell under normal conditions. The business is not in the woods in those particular territories. Why should we make the mistake of burning up a lot of money trying to do the impossible? There are thousands of communities where sales can be made. Let us pick them out and put the best one at the top and the next one below it and so forth, listing them according to the sales resistance. Let us not burn up big appropriations advertising to dead ones. Advertise to live ones. Work the spots that are good for all that is in them.

We are in the refrigerating business. The other day I found that we had all our efforts concentrated up where icicles were hanging off the windows, in Minneapolis. You can imagine going in to see a prospect who, while he is ruminating on whether he will buy, sees a large icicle hanging onto the window. I said, "Why in heaven's name have we not got those men down in Florida where it's hot?" What blunders we can make if we do not go at the thing analytically all the time! Let us know our territories and demand from those where the business is the ultimate. Put the money in there. See to it that we have the backbone to tell that distributor in that territory, "You get that business," and lead him on to get it. It can be done. It will save us a large amount of money somewhere else.

Manufacturing Economy

On the manufacturing end of the business every economy that can be effected should be put into force. I am not in sympathy this year with the idea of saving half a cent on some operation and getting a $20,000 machine to do it; or with the wonderful expert who specifies where an operation comes in proper sequence, if we have to upset our factory to follow his instructions. I am not in sympathy with changes that are merely for looks or for whimsical reasons advanced by a fellow who is not a business-man, and takes out one row of machines and substitutes another that is entirely different. I have had the experience, after being away from the factory for a couple of weeks, of going down some familiar aisle and seeing something changed. I said, "Where are those grinding machines?"

"Well, you see, on account of doing such and such we had to take those out and put these in."

"What for?"

"Well, on that operation we saved a quarter of a cent."

I said, "Yes, and it will take you 1,000,000 years to get it back again."

I do not want to indicate that we should not have breadth of view in our management, or that we should not look into the future and get our costs down as low as we can. But, instead of proceeding in a highly technical way because we want to show what a wonderful shop we have, let us act in a business way. Then probably we will not make the proposed changes in 1922 at all. Let us consider the suggestions, make up a 1923 book, and begin jotting down the things that we should be planning for 1923. In our particular case I have issued a note that there will be no more moving this year. We will not do any moving until 1923. We have been in business 5 years and we have moved and moved until moving is our second name. Consequently, we are going to stop moving and stay right where we are for 1922.

Business Sense Essential

The point I am trying to make in citing the rather extreme instance is that I want the head of that maintenance department to be a business-man. Heretofore he has been the champion mover of the world; and he has been a good mover. He takes pride in his ability to move the Herculean machines and swing them over poles. But what would he do to the profit and loss sheet this year? I issued the order I mentioned so that he would get the business slant. Rules are made to be broken, however. If that man should prove that he could put $50,000 onto the profit and loss sheet, an exception would be made. He has to prove his case. After he has learned that there is something in the world besides having the ability to move Eiffel Tower without breaking it into pieces, he will be worth much more to the business.

I am not in sympathy with these men writing in books that nobody ever looks into. You go through your place and see a fellow with a huge book with little curlicues all over it; 4 years ago some fellow originated that book.

He hasn't looked at it for 3 years. Let us get that all out.

We used to be guarded to death. We had 34 men, I think, protecting the property. You would have thought the place was made of chocolate and all the kids were going to come in and lick it up. Sweep? We used to sweep until we could see the grain right down through the boards. Let us not look at the floor so much. It is a good idea to paint the edges white so the men will not squirt tobacco juice into the corners, but let us stop being sweepers, guarders and movers. Let us get over onto the profit and loss sheet.

One fine way to do it is to get a budget that cannot be broken. But that budget should be developed by team-play and not by coercion. We do not want a factory full of sour people. Get the budget by cooperation. Once any man in any department has the viewpoint that the real sport in business is in making the business sound, you have no difficulty in getting him to play the game with you. It is when he thinks you do not appreciate what a wonderful engineer he is, or what a wonderful sales-manager he is, it is when he has the prima-donna attitude, that you cannot get him to cooperate. When it can be shown that a greater tenor is the fellow who can write in black instead of red, you do not have any difficulty in getting the cooperation you want.

The Engineer's Period

I think that the engineer can do much in this business situation. In fact, I think that it is the engineer's period, and that he can take the place of the promoter. As I have indicated, you could get away with murder in business; you could make a thing almost any shape and without any appeal and, because they could not get good stuff people would take bad stuff. That day is over. We must give them the values, at the right prices; we must sell things that really have intrinsic merit. We have to take the attitude that with our product we are buying the other fellow's money; he is not buying it; we are buying dollars from him with it.

I believe the engineer can help in the situation by going to the general manager of his company and saying, "I want to know more about this business. I think I can help you out if I get a real business understanding of the whole proposition. I would like to meet with the manufacturing man and find out what it is that I can do to help you most." I will guarantee that there are many brilliant chief engineers in this Country who have no particular business viewpoint so crystallized in their mind that it is right in front of them every minute. We need cooperation badly. If the man at the head of the engineering department has the right attitude, he will transmit it to every member of his force; he has many men under him who can help him arrive at what he wants to do.

See if this applies in your business. For 6 years we have been working to perfect lighting-plants. We have in mind a product far beyond what we are delivering to the public at the present time. What have we been doing all those 6 years? We have been making the product better, bringing out a new model from time to time. We have been projecting into the future something that has in it greater facilities for serving the public. Can we not take from the engineering department all of the knowledge accumulated and swing it into only those things that will help us in the year 1922? Analyzing our situation, we found that we could. We will call 1000 of our salesmen together in a convention and present to them something that they can sell and make money out of, and add to the machine-hours in our factory. The engineer can analyze his accumulated experience and should see what he can do with it to make his product better this year.

In addition, the engineer can help very materially by studying every known method of producing at the lowest possible cost just as good an article as has been produced. Moreover, he can assist by studying the engineering changes he wants to put into effect. There are two types of engineering change. There is the engineering change that should be adopted immediately because the service department has indicated a weakness in a particular feature. The weakness is constantly bobbing up and we are pouring money out in service as a result. The more quickly we can cure the trouble the better. The other type of change, which is made more frequently, is actuated by theoretical considerations with a view to improving the product. Let us put that over until 1923. In other words, look at the matter purely from the customer's standpoint. If he is being served properly with the product as it stands, leave it alone; if not, put the change into effect. Great economies can be had by leaving the product alone. It costs the factory considerable money to change over to suit a particular engineering modification, including the expense of shifting machinery. When you decide upon a change you do not perhaps take something else into consideration which, not being in the right relationship, involves another change. It is like small-pox; it breeds fast if you do not look out.

The engineer can help wonderfully by using the very best of business sense in handling those changes that come through. This applies not only this year; it always applies. The engineer should be in touch with the selling end of the business. Then he can do much more in designing articles that appeal to the public strongly than if he shuts himself up in an office and does not know what is going on. Getting out and seeing the product in use is the thing that counts. I believe that the engineering staff should be sent out to service the product, just as much as possible. No service-man can go out and ascertain the exact condition of things and come back and make a desk engineer understand what he is talking about. But if Mr. Engineer goes out and dirties his lily-white hands mussing around with the product, you can bank on it that the next time he designs a model it will be "right-side-up" and of such construction that you can take a screw out when you want to.

Improved Business in Prospect

I look forward to this year being a very much better one than last year. I think that wonderful work was done last year in "getting back to earth." The process will have to continue in certain lines, but in the main business will improve on a sound basis. Do not take that as the final thing; we shall slow up again, come down again, until we finally get to the point where all things will be lined-up in the proper proportion. Let us understand that situation; let us do our part in shaping our product so we can make a profit on less sales than we used to get, because all of us cannot get as many sales as we used to get, when there is not as much buying-power as there used to be. We must operate our plants on the basis of the amount of sales we can get. If we do not, there is only one answer: some of us will be eliminated in the shuffle. We want to "put it across," and the way to put it across is to line-up in team-play, every man a business-man: every man, though he is a specialist in his own line, seeing to it that his viewpoint and the thing that he does are in the direction of putting his company where it ought to be.

Developing a Method for Testing Brake-Linings

By S. von Ammon[1]

Annual Meeting Paper *Illustrated with* Charts and Photographs

As a result of the general policy of the Motor Transport Corps to standardize the materials used for automotive vehicles for Army Service, in cooperation with the Bureau of Standards, the Society of Automotive Engineers and the automotive industry, the Bureau of Standards has been engaged for some time in developing a standard method for testing brake-linings. While the work is not completed, much information has been gained. This paper reports the progress of the work.

The equipment developed and the methods used for both main and supplementary tests are described. Information is given regarding the coefficient of friction, as influenced by various factors. The endurance test, showing the comparative behavior of linings under conditions similar to those of severe service, is believed to be satisfactory as developed. Further work is necessary before recommending the conditions for the other test, intended to determine the relative endurance under ordinary or light service. In work done so far with a cooled drum and over a very wide range of power absorption and speed, difficulties arising from the accumulation in the lining of particles of steel cut from the drum have persisted. Supplementary tests covering the tendency of a lining to stick when brakes are left applied on a hot drum, and to ascertain the relative absorption of oil and water, are described. The influence of oil and water on the coefficient of friction is shown.

THIS paper is presented as an account of the progress and present status of the investigation of brake-lining materials with which the Bureau of Standards has been occupied for some time. In addition to its general interest, it is hoped that the information offered will be of assistance to those who are about to take up, or have recently begun, experimental work along similar lines, with apparatus identical with that developed at the Bureau of Standards.

The investigation of brake-lining materials by the Bureau of Standards was undertaken as a result of the general policy of the Motor Transport Corps to standardize the requirements for materials and supplies for automotive vehicles for Army service, as outlined by its representatives on several occasions before the Society, in cooperation with the Bureau of Standards, the Society of Automotive Engineers, and the automotive industry. Many tests of brake-lining materials had been made in the engineering laboratories of the Motor Transport Corps in 1917 and 1918. At that time, however, it was not possible to devote much study to the determination of the most satisfactory conditions for a laboratory test. The conditions under which manufacturers of brake-lining materials had tested their products and under which acceptance tests were made by car builders were so varied that results were not comparable, and had yielded but little information. This lack of definite information and a recognized method of test made it necessary to develop a standard test for determining the relative merits of brake-linings, which could be used as a basis for specifications. In December 1919 a Subdivision of the Truck Division of the Standards Committee of the Society of Automotive Engineers, consisting of A. K. Brumbaugh, of the Autocar Co., chairman; W. T. Norton, Jr., chief engineer of the Motor Transport Corps; Dr. H. C. Dickinson, of the Bureau of Standards; and Clarence Carson, consulting engineer of Johns-Manville, Inc., formulated a tentative program for developing a standard method for testing brake-linings and invited brake-lining manufacturers to have engineering representatives attend a conference at the Bureau of Standards on Dec. 18, 1919, to discuss the proposed program. The equipment designed jointly by the Motor Transport Corps and the Bureau of Standards, and built by the former, was completed so that preliminary tests could be begun in August 1920.

Various modifications were found necessary during the preliminary work and these, together with others tending to improve operation and convenience in handling, were made from time to time at the Bureau. In view of the progress made, the Bureau of Standards invited representatives of the Motor Transport Corps, the Society of Automotive Engineers, and brake-lining and automobile manufacturers to a conference at the City of Washington on May 17, 1921. At this conference a report of the work done at the Bureau was given. Tentative recommendations for various parts of the test were offered by the Bureau, subject to modification as a result of further work planned chiefly to overcome difficulties encountered in the endurance test with a cooled drum. After completion of the preliminary work at the Bureau early in 1921, several brake-lining manufacturers, constituting a Subdivision on Brake-Linings of the Parts and Fittings Division of the Society's Standards Committee, built equipment following the design developed at the Bureau.

Since the conference of May 17, 1921, the Bureau has furnished complete drawings to all brake-lining manufacturers and other interested parties and, so far as is known, about one-third have had such equipment built. This represents 8 or 10 equipments in addition to that at the Bureau. It is hoped that the carrying on of experimental work on the same lines at many points will assist in overcoming difficulties encountered, bring to light any possible defects in apparatus or methods and result in an early agreement on a wholly satisfactory method for the test.

The cooperation of those participating is acknowledged, the Motor Transport Corps furnished the original equipment and supplies and provided a large part of the funds required; Mr. Carson aided with suggestions at different times and, on behalf of Johns-Manville, Inc., delegated H. Copleston to the Bureau from October to December 1920 to assist in the carrying out of the preliminary tests made during this period. Liberal supplies of sample lin-

[1] Associate mechanical engineer, Bureau of Standards, City of Washington.

FIG. 1—TEST EQUIPMENT AS USED FOR TESTS WITH UNCOOLED DRUM

ings required for the tests, which necessitated frequent repeat tests, have been furnished to the Bureau from time to time by nearly all the manufacturers; these samples included many experimental ones not yet in regular production, the latter being of particular value in this work inasmuch as some at least represented probable future developments. The actual tests have been made by H. H. Allen, under my direction, in the automotive power-plants section of the Bureau of Standards.

GENERAL CONSIDERATIONS

The various features which it was thought required investigation are shown in the following abbreviated form of the orginal program, including some slight modifications and additions resulting from the discussion at the conference of Dec. 18, 1919. Its main divisions are considered as (*a*), fundamental, and (*b*), supplementary. Under (*a*) the coefficient of friction is investigated in relation to

(1) Dry lining
(2) Influence of water, oil, temperature and wear
(3) Constancy of the coefficient

Durability also is studied under (*a*), it having been decided to adopt the following:

(1) A standard rate of energy input, with consideration of established practice and limited to engine power
(2) A drum of standard material and surface, and 12 to 16 in. in diameter, at a speed of about 1200 r.p.m.
(3) Stock sizes of linings; preferably, the actual size considered
(4) A policy of wearing linings down to about one-half of their original thickness
(5) A long-time endurance test with the temperature kept constant by cooling water
(6) A severe-service test, the temperature of the drum being allowed to rise to equilibrium with constant power-absorption

The supplementary division includes

(1) Rivet-holding ability
(2) Sticking after cooling on a hot drum of both new and worn linings
(3) Change of thickness due to the absorption of water and oil

The general considerations are inclusive of the

(1) Use of flexible-band shoes for supporting linings
(2) Adoption of a standard method of riveting samples to shoes
(3) The determination of the proportion and quality of asbestos and other materials used is not considered necessary, nor is a test for volatile matter thought important

It has been the aim throughout to develop simple equipment and methods that would not entail a large expenditure for apparatus or require exceptional skill or judgment to obtain results of sufficient accuracy. In view of the nature of the materials dealt with and the many factors influencing the results, it is satisfactory if the test results are accurate within 5 per cent. The methods used permit a much greater accuracy than this.

The conditions of a laboratory test of this kind should approximate as nearly as possible those existing in actual service. It is desirable, however, to accelerate the testing of a sample and, for this purpose, it is permissible to depart from actual service conditions so long as the test results continue to indicate fairly the relative ability of the materials tested, under service conditions. This applies to both the coefficient of friction and the comparative endurance of various linings. At different times during the investigation it was found that conditions appearing suitable with some linings proved less so with others, and this made additional work necessary.

In establishing the conditions for the tests, sufficient latitude should be allowed for new and improved materials likely to be developed in the near future. No conditions should be included as a part of either tests or specifications that might place unnecessary restraint on the choice of materials or methods of manufacture, other than the ability of the finished product to render the service required. At present, information available regarding the composition of linings and its influence on their behavior in operation is too scant to base specifications on more than service tests made either in the laboratory or on the road. Systematic investigations of the materials and treatments used will be made, however, and may show their influence on the results in service. When the knowledge in this connection is sufficient, limitations covering the composition can be included in specifications.

EQUIPMENT

Figs. 1 to 3 show the equipment used. A standard brake-drum 14 in. in diameter and 2½ in. wide, a size in extensive use and therefore readily obtainable on the market, is mounted on the end of a shaft that can be driven by any conveniently available power as shown in Figs. 1 and 2. The sample linings bearing on the outside of the drum are riveted to two flexible steel shoes which in turn are mounted in a framework, as shown in Fig. 3. The position of the upper arm *a* is fixed, while the lower arm *b* is movable about the joint *c*. An adjustable tension-rod *d* and spring-balance *e* placed between the free ends of the pressure-arms serve to regulate and measure the pressure with which the shoes are

pressed against the drum. An extension of the frame *f* forms a torque-arm and rests on platform scales for measuring the torque. The whole frame is suspended from above over small pulleys, and its weight is counterbalanced to equalize the pressure on the upper and lower shoes. The drums are of low-carbon steel, the material most generally used at present. Each lining sample is secured to its steel shoes by eight brass tubular rivets, with a definite spacing adopted as standard, the rivet-holes in the lining being drilled carefully and countersunk to a fixed depth of about one-half the lining thickness. The samples are 2 in. wide, ¼ in. thick and 11 in. long, each covering 90 deg. of the drum. The total area in contact, after deducting the area of the rivet-holes, is 42.75 sq. in.

From the dimensions shown in Fig. 3 it will be found that

$$hp. = 0.000444\,W\,S \qquad (1)$$
$$Q = 10\,P \qquad (2)$$
$$U = Q \div 42.75 \qquad (3)$$
$$f = F \div Q$$
$$= LW \div RQ$$
$$= 4W \div Q \qquad (4)$$

where

$hp.$ = horsepower
W = force acting at the end of the torque-arm, in pounds
S = speed, in revolutions per minute
Q = total pressure on the linings, in pounds per square inch
P = force between the tension-arms, in pounds, as indicated on the spring-balance
U = unit-pressure on the linings in pounds per square inch
f = coefficient of friction
F = force at the circumference of the drum, in pounds
L = length of the torque-arm, 28 in.
R = drum radius, 7 in.

The wear is checked by measuring the change in distance C between the prick-punch marks just below the knife-edge seats at the ends of the two tension-arms; then, $(C_1 - C_2) \div 10$ = the average thickness loss in inches of one lining sample. To dampen the movement of the weighing-beam of the platform-scale, a small dash-pot is connected with the end of the arm. This is not shown in the photograph, because it is unnecessary when the torque is measured by an electric dynamometer. One end of the upper shoe is kept in a fixed position relative to the frame by the braces *g*, to prevent sidewise travel of the whole frame when in operation. Fig. 1 shows the open, uncooled drum, mounted; and Fig. 2 shows the covered drum for water-cooling.

Coefficient of Friction

The coefficient of friction of fabric brake-linings is influenced by many factors. Among these are the unit pressure, the surface speed, the temperature and the condition of the wearing surfaces. The last differs not only as a result of the varying methods of manufacture, but changes constantly as wear progresses. It was found that the changes in the coefficient of friction that the preliminary tests showed as resulting from varying speed and pressure at constant drum-temperature are comparatively small, and that other considerations that are referred to later are more important in limiting the choice of speed and power-absorption for a practical test.

Comparing the values of the coefficient of friction as obtained during extended runs with the speed or the horsepower constant and the other variable changed, the average and the maximum values of the coefficient reached during various parts of such a run show no consistent variation. It is not only very difficult to establish any definite relation between these values but, in view of the great difference in linings, the infinite number of possible combinations of service conditions and the many factors influencing the coefficient, the establishing of such relations proves of comparatively little value. It appears that the aim of manufacture should be to produce material that will have a reasonably constant coefficient of friction; that the coefficient, under the most unfavorable conditions and even for very short periods, should not go below a certain minimum value; and that, in addition, the material should show the longest possible life. The minimum values of the coefficient of friction, from 0.11 to 0.25, obtain during severe service and

Fig. 2—Test Equipment as Used for Tests with Cooled Drum and Oscillator

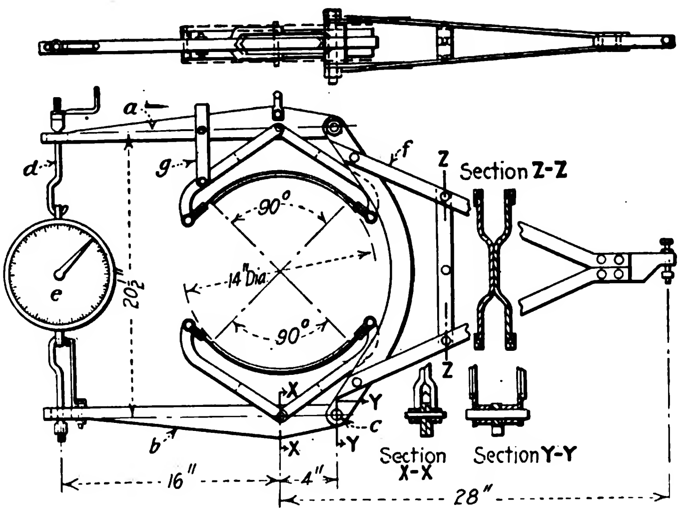


Fig. 3—Assembly Drawing of Brake-Lining Test Mechanism

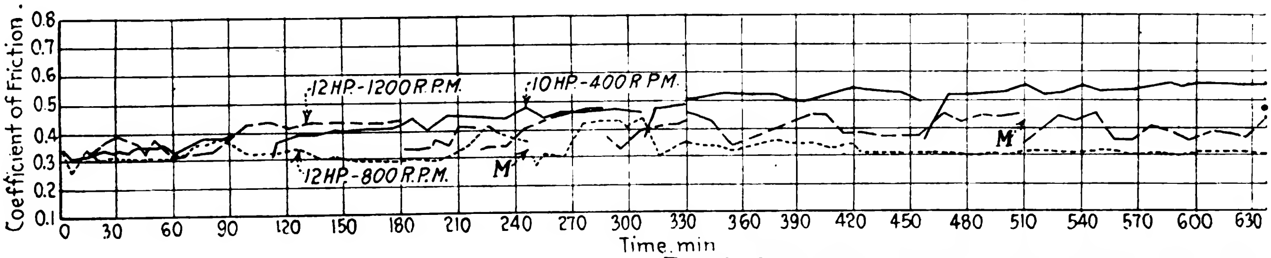


FIG. 10—COEFFICIENT OF FRICTION WITH COOLED DRUM WITH

high temperatures; usually, for only short periods, although in some cases they have been observed to persist for a period of from 15 to 60 min. The lowest value reached with a given lining frequently is higher with a

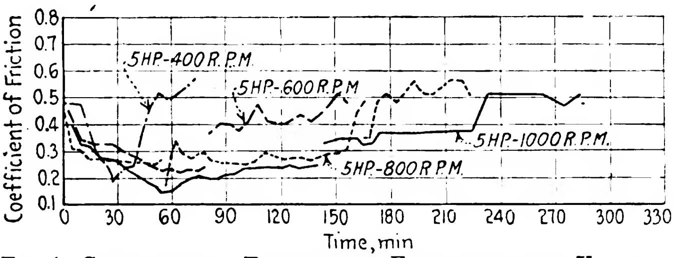


FIG. 4—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM AT 5 HP. AND 400, 600, 800 AND 1000 R.P.M.

combination of speed and horsepower that is not the most severe as regards the endurance of the particular lining.

The lowest values result from the action of the heat

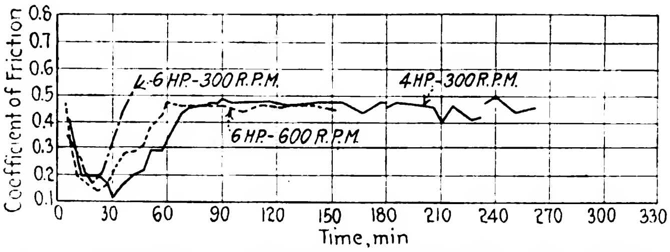


FIG. 5—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM WITH 4 HP. AT 300 R.P.M. AND 6 HP. AT 300 AND 600 R.P.M.

on the impregnating compounds during the severe-service runs, as is seen from the character of the curves in Figs. 4 to 7. When this change has taken place, the coefficient rises again and remains high during the remainder of the run. It seems necessary therefore to design brakes so as to reduce the maximum temperature occurring insofar as that is possible, or to employ only impregnating compounds having high heat-resistance, to reduce the drop in the coefficient that results from high operating-temperatures. This effect is seen by comparing the curves relating to the tests made with an uncooled drum and those made with a cooled drum.

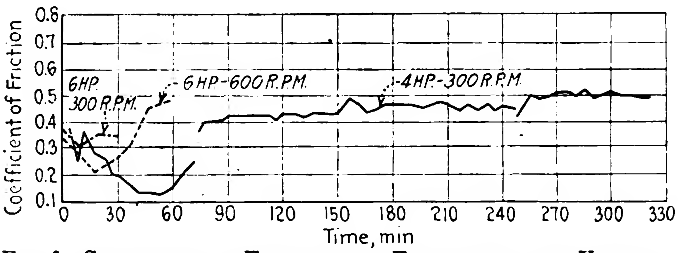


FIG. 6—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM WITH 4 HP. AT 300 R.P.M. AND 6 HP. AT 300 AND 600 R.P.M.

Compounds having a high heat-resistance also lengthen the life of the lining insofar as their capacity for binding the asbestos fibers together is maintained better throughout the life of the lining. This is indicated by the results, which show that the linings with the longest life maintain their minimum coefficient over shorter periods than linings with a shorter life.

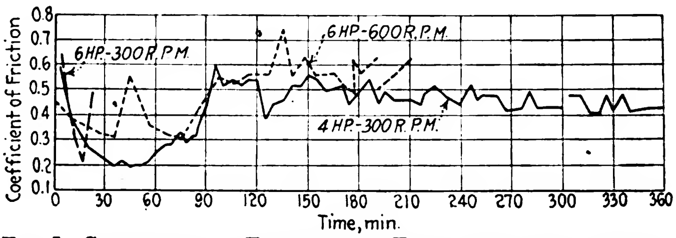


FIG. 7—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM WITH 4 HP. AT 300 R.P.M. AND 6 HP. AT 300 AND 600 R.P.M.

In view of the wide variations in the coefficient of friction and the low values reached at times, it is necessary, of course, to base the design of brakes on a reasonably low value of the coefficient. In addition, allowance must be made for the application of a pedal pressure considerably higher than normal during the periods when the coefficient is reduced to its minimum value as a result of continued severe application and the consequent heating, particularly as the minimum value may occur when braking power is most needed. Comparing the coefficients found during the runs with cooled and uncooled drums, it is found that, with the cooled drum

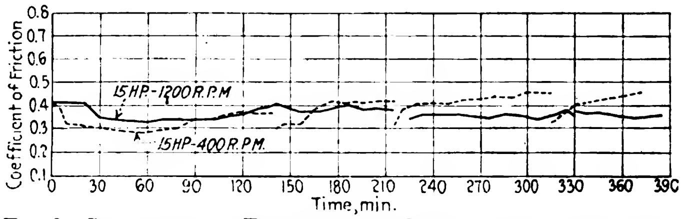


FIG. 8—COEFFICIENT OF FRICTION WITH COOLED DRUM WITH 15 HP. AT 400 AND 1200 R.P.M.

(1) The rapid drop, characteristic of the early part of the run with an uncooled drum, is absent
(2) The changes with the cooled drum are not so rapid, nor as large

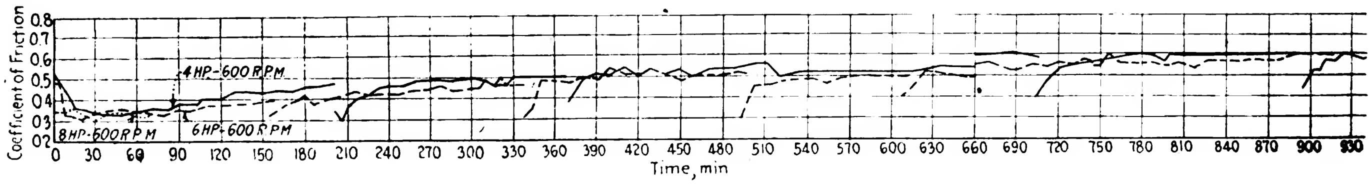
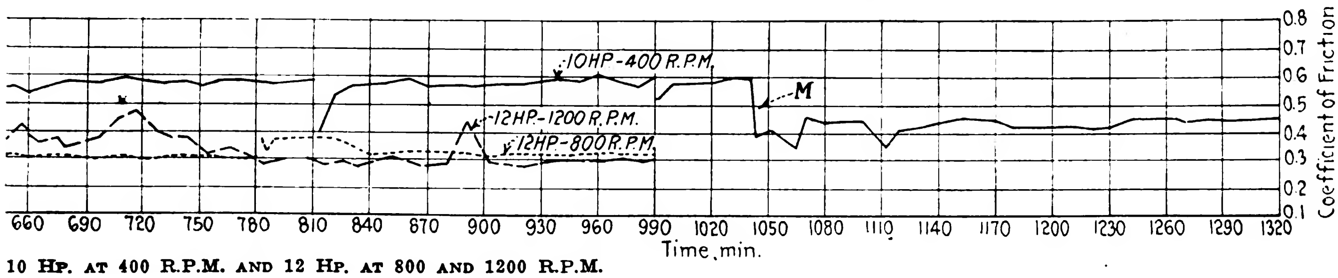


FIG. 11—COEFFICIENT OF FRICTION WITH COOLED



10 Hp. at 400 R.P.M. and 12 Hp. at 800 and 1200 R.P.M.

(3) The minimum values do not reach the low levels resulting from the high temperatures in the severe-service run

Figs. 8 to 12 show the range of variation in the coefficient over a wide range of speed and horsepower on a cooled drum. The coefficient of friction is plotted against time. The several curves in each figure were obtained by making tests on different samples of the same lining. Fig. 12 applies to the same lining as that in Fig. 11, but gives the results with much increased unit-pressures. The samples in this case had only 37 per cent of the normal area and consisted of pieces 1⅜ in. long; three were riveted to each shoe, one in the center and one at each end. The unit-pressures in this case ranged from 28 to

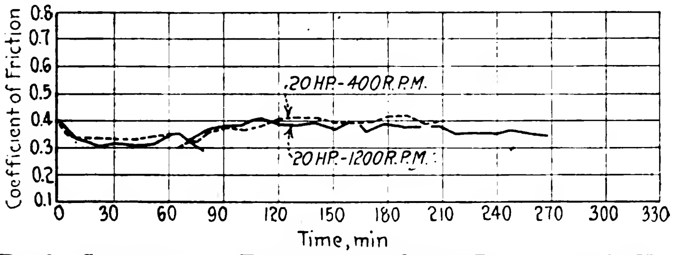


Fig. 9—Coefficient of Friction with Cooled Drum with 20 Hp. at 400 and 1200 R.P.M.

42 lb. per sq. in. All of these results, as well as those obtained with speeds of from 400 to 1200 r.p.m. and a power input of from 25 to 40 hp., indicate that we need not be limited by the variations occurring in the coefficient of friction in the selection of a suitable combination of speed and horsepower for the test with cooled drum; the limitations to be observed result from other considerations, which are stated later herein.

A number of similar comparisons relating to tests with an uncooled drum are shown in Figs. 4 to 7 and Fig. 13; here we find again that the variations in the coefficient of friction are not the important factor in determining the most suitable combination of speed and horsepower for these tests. Table 1 shows the maximum, minimum and average values of the coefficient of friction, determined from all the tests that were made.

TABLE 1—RANGE OF THE COEFFICIENT OF FRICTION

	Cooled Drum	Uncooled Drum
Maximum	0.75	0.75
Minimum	0.25	0.11
High Average Value for Run	0.60	0.60
Low Average Value for Run	0.33	0.32
Majority of Averages between	0.35 and 0.45	0.45 and 0.50

Periodic fluctuations in the coefficient are more marked in some linings than in others; certain combinations of speed and horsepower may tend to increase these fluc-

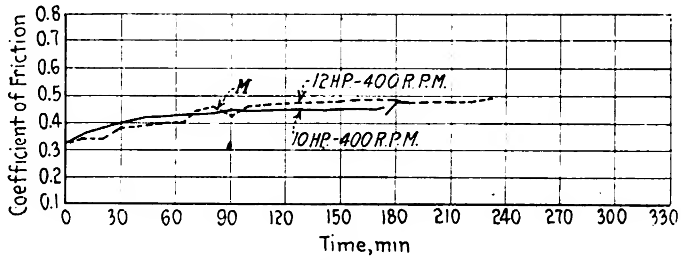


Fig. 12—Test with High Unit-Pressures with Cooled Drum with 10 and 12 Hp. at 400 R.P.M.

tuations in a given lining. The more pronounced the tendency to such fluctuations is, the greater the tendency to seize, squeak and chatter will be.

Comparisons that have been made between linings of the woven and the folded and rubberized types do not indicate that maximum, minimum or average values vary markedly as a result of these two methods of construction. The wide range over which the coefficient of a given lining varies and, particularly, the low values to which the coefficient in practically all linings drops during the early part of the severe-service test, are points of special interest. These low values are, in most cases, much below the average values obtained later during the severe-service run, and are also below the average of the endurance test with a cooled drum. Although appearing only during the early part of the tests, they may occur in service at any time and may continue for long periods, depending entirely upon the use made of the brake from time to time and are therefore the more undesirable.

During the preliminary tests with the cooled drum, a number of temperature measurements were made by in-

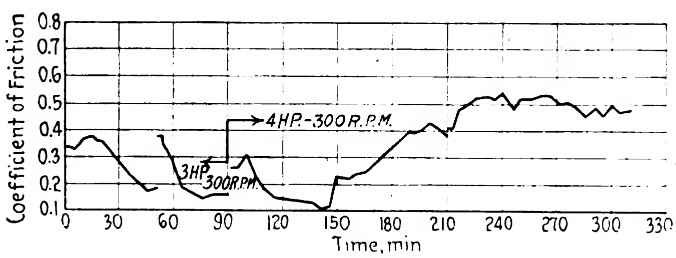
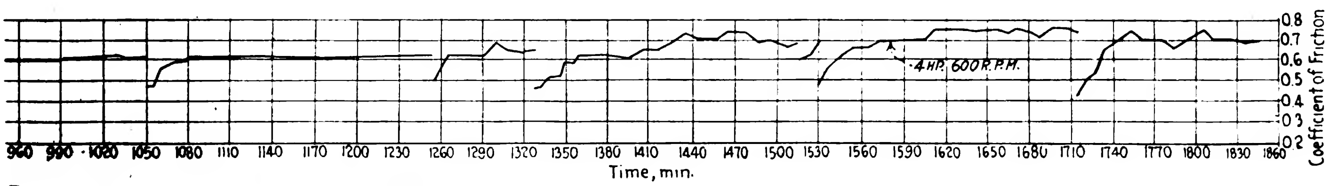


Fig. 13—Coefficient of Friction with Uncooled Drum with 3 Hp. at 300 R.P.M. Followed by 4 Hp. at the Same Speed



Drum with 4, 6 and 8 Hp. at 600 R.P.M.

serting thermocouples between the lining and the shoe at both the entering and the leaving ends of each sample. The temperatures measured ranged from 150 to 200 deg. cent. (302 to 392 deg. fahr.). In some of the preliminary severe-service tests some parts of the drum became red-hot for short periods. However, at the speed and horsepower adopted for this test with an uncooled drum, it is estimated that the temperature at the face of the lining lies between 250 and 450 deg. cent. (482 and 842 deg. fahr.).

Influence of Oil and Water on the Coefficient

The influence of oil and water on the coefficient of friction is shown in the curves in Fig. 14. The samples used were standard samples that had been worn-down in previous tests to about one-half their original thickness. As noted on the charts, the first two groups had been subjected previously to tests with a cooled drum, so that the impregnating compounds were substantially in the original condition. The last two curves were obtained with samples that had undergone severe-service tests with an uncooled drum; here the impregnation had been carbonized, leaving the lining in a more absorbent condition. All of the tests with oil and water were made on a cooled drum and the linings were first run dry until the coefficient of friction had become steady.

The lining to which the first curve refers, sample No. 30 (A-1), was then submerged in oil at 100 deg. cent. (212 deg. fahr.) for 1 hr., the test was resumed and, during the period marked in the plot, oil was swabbed on the drum. The two curves in the second chart refer to a folded and to a woven lining. During the period shown water was sprayed on the periphery of the drum at two opposite points between the shoes. In the case of the last two charts, water was applied for the periods shown

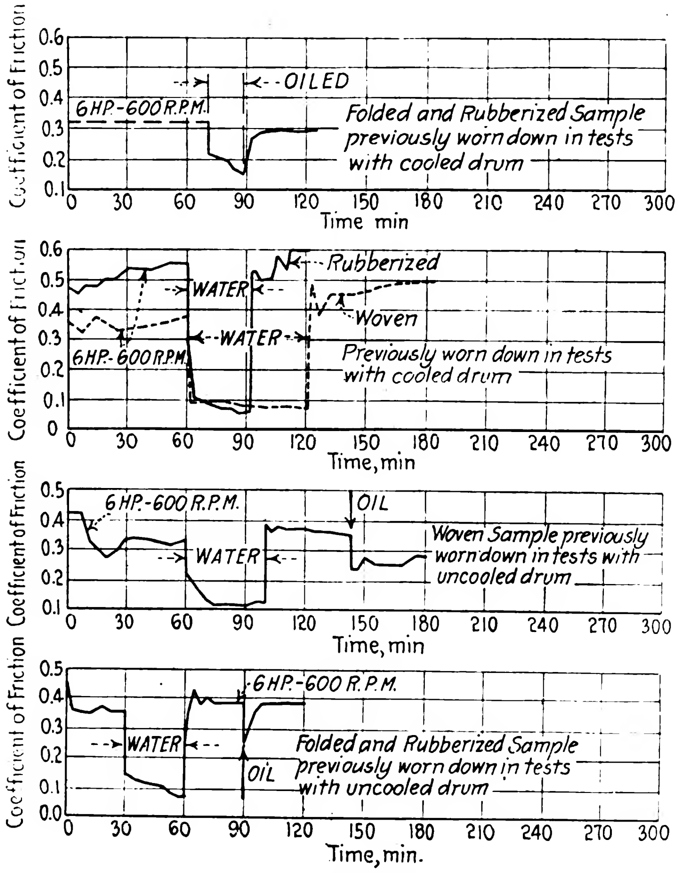


Fig. 14—Influence of Oil and Water upon the Coefficient of Friction

Fig. 15—Samples Showing Steel Particles Embedded in the Lining after a Test with the Cooled Drum

and as already described. After continuing the run for a time without water, these linings were thoroughly soaked in oil; the oil was not heated in this case, as the absorbent condition of these two linings made this unnecessary. The drum was also well-oiled. The very marked drop in the coefficient of friction resulting from the application of oil as well as water, is clearly shown in these curves. It will be noted also that when the application is discontinued the coefficient rises very rapidly to approximately its former value. In the third chart, sample No. 53 (A-15), the low value of the coefficient continues for some time as a result of the absorbent condition of the lining.

The fact that water is expelled and evaporated more rapidly than oil is shown by the quicker rise in the coefficient as shown in the curves, in comparison with the rise when oiling is discontinued. Nevertheless, it is important that the changes in the coefficient of friction resulting from the presence of surface water or moisture absorbed by the lining should be small. With a well-designed axle the amount of oil reaching the brakes should be very limited and, as this oil is confined usually to only a part of the braking surface, the effect of oil as shown by the curves can be considered as being extreme, and to be expected only where undue oil-leakage takes place.

Endurance Tests With a Cooled Drum

From the first, it has been considered advisable to make two distinct tests for durability to establish the behavior of a lining under the varying conditions to which it may be subjected in service. The user would thus be able to select linings in accordance with the average service for which they are intended. These conditions differ not only with wheel and propeller-shaft or transmission brakes, but with the design of the vehicle and the general topography of the locality in which the car is used.

Fig. 2 shows the covered and water-cooled drum used in the tests with controlled drum-temperature. A flow of water is maintained by the feed and siphon pipes shown, and it is regulated so as to maintain the temperature of the water close to the boiling-point. To accelerate the tests, the first work was done with a high drum-speed and high unit-pressures. Short preliminary runs indicated that, with a speed of 1200 r.p.m., 30 hp.

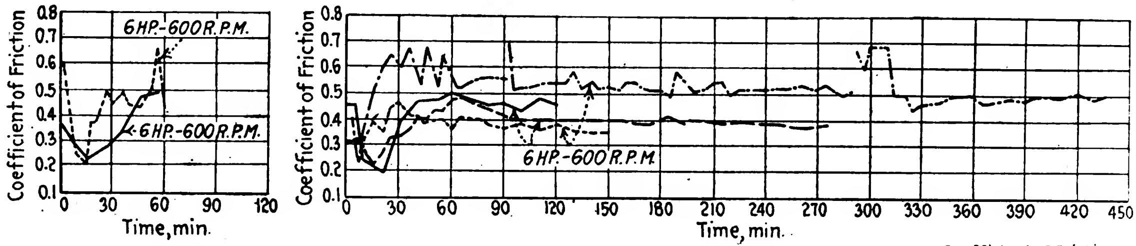


FIG. 16—COEFFICIENT OF FRICTION AND ENDURANCE TEST OF LININGS OF SMALL (AT THE LEFT) AND MEDIUM (AT THE RIGHT) ENDURANCE

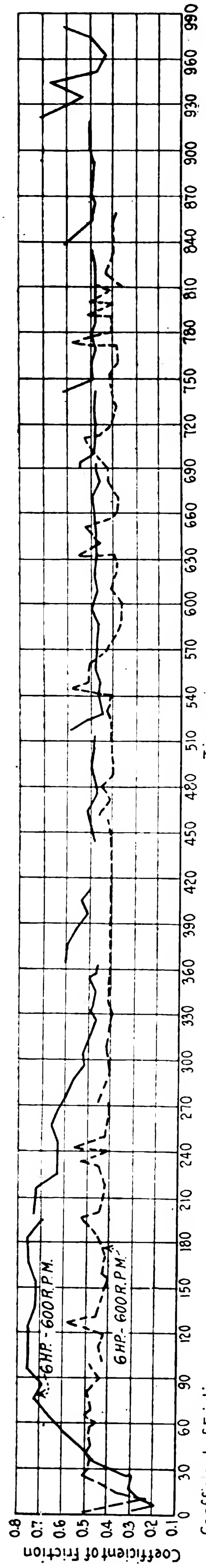


FIG. 17—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM AT 6 HP. AND 600 R.P.M.

or even more might be absorbed. However, more extended tests showed that, under these conditions, the linings cut the drum and the steel removed imbedded itself in the lining and grooved the drum severely. This condition was not improved materially in successive tests with power reduced to 10 hp. and speeds between 1200 and 600 r.p.m. An oscillating device was, therefore, connected with the frame of the apparatus. This device consists of a small worm-gear driven from the dynamometer and connected with the frame so as to move it back-and-forth about 1/4 in. over the face of the brake-drum once in every 52 revolutions of the drum, as shown in Fig. 2. By this means the scoring was reduced and the grooving of the drum prevented by distributing the cutting action over a greater portion of the face.

Many tests were made in regard to power absorption, resulting in unit pressures of 96 down to between 2 and 3 lb. per sq. in., which is equivalent to from 40 to 4 hp., and speeds from 1200 to 400 r.p.m., using representative samples of the woven, folded and molded types. In all cases, however, cutting and imbedding of the metal in the lining was found. The fine particles first lodging in the lining increased the cutting action and caused additional steel to gather and, probably due to local heating, the accumulated metal was fused together until, in very severe cases, irregular pieces were found, some of which had an area of about 1 sq. in. and a thickness of from 1/32 to 1/16 in. The tests with samples of reduced area, referred to previously, formed part of this series. It was thought that, with such short samples, there might be less tendency of the steel to accumulate in the linings, but this was not found to be the case.

The point at which this cutting occurred varied according to the power absorption and speed. The tests indicate that it generally begins soon after the face of the lining is worn down to a smooth surface, when the wires are first exposed. Fig. 15 shows selected samples with imbedded steel. The beginning of the cutting usually can be noticed clearly on the drum by the appearance of a narrow band, and slight fluctuations in the coefficient result. When the metal begins to accumulate in the lining, there is a decrease in the coefficient which is marked at times, as is shown in Fig. 10 at the 1050-min. point.

It will be seen that these circumstances make it very

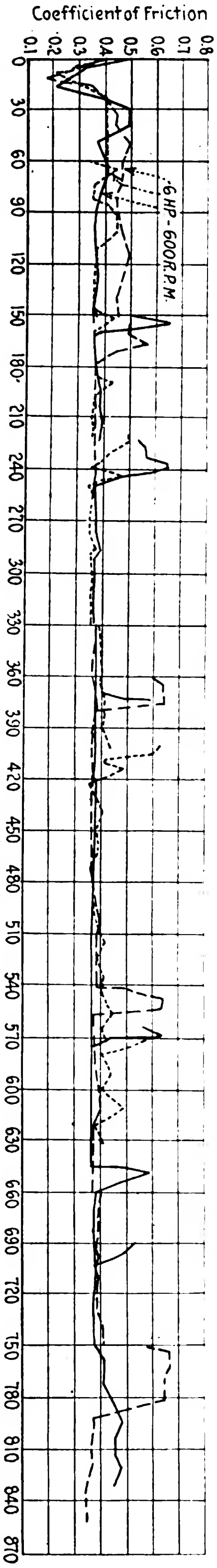


FIG. 19—ENDURANCE TEST WITH THREE SAMPLES OF THE SAME LINING AS THAT AT THE RIGHT OF FIG. 18

FIG. 18—CONSECUTIVE ENDURANCE TEST WITH THREE SAMPLES OF EACH OF TWO DIFFERENT LININGS

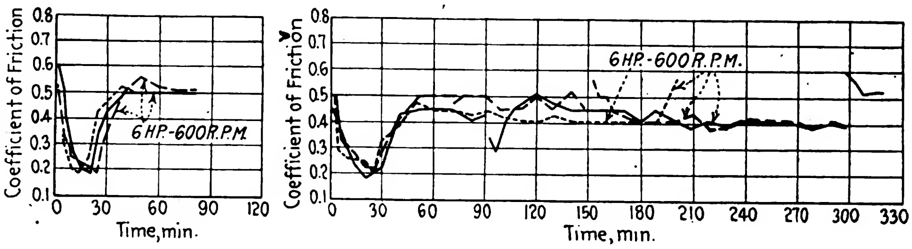


Fig. 20—Appearance of Linings after Severe Service Test
The Upper Pair Are Two Views of a Typical Folded and Rubberized Lining, While Below Is Shown a Typical Woven Lining

difficult to determine conditions for this test in a satisfactory manner. If conditions are adopted that tend to delay the cutting action, the time required for a test will not only be inconveniently long, but the wear will be so small that it will be difficult to determine the relative durability fairly; and no data will be obtained covering either the coefficient of friction or the durability of the center of the lining. Some linings probably have a greater tendency to cut the drum than others; if this is so, it would be desirable, of course, to have the test show this and thus lead to improved construction. However, in view of the many variables which enter, there is small prospect of obtaining accurate and reliable information on this feature.

Accumulation of metal does not occur during the tests with an uncooled drum, presumably because the holding power of the impregnating compounds has been destroyed by the high temperatures, and steel particles are carried off with the asbestos as wear proceeds. The use of the oscillating device constitutes a departure from service conditions and, therefore, it is of interest to note that with a number of samples tested, both with and without an oscillator, the differences in the coefficient of friction were negligible. During the continuance of the tests with a cooled drum, there is no apparent change in the nature of the impregnating compounds. In brake-linings worn-down in actual service, particles of steel are found only occasionally, but the continuous application of the lining to the drum during the test appears to result in a greater tendency to collect the metal particles in the lining.

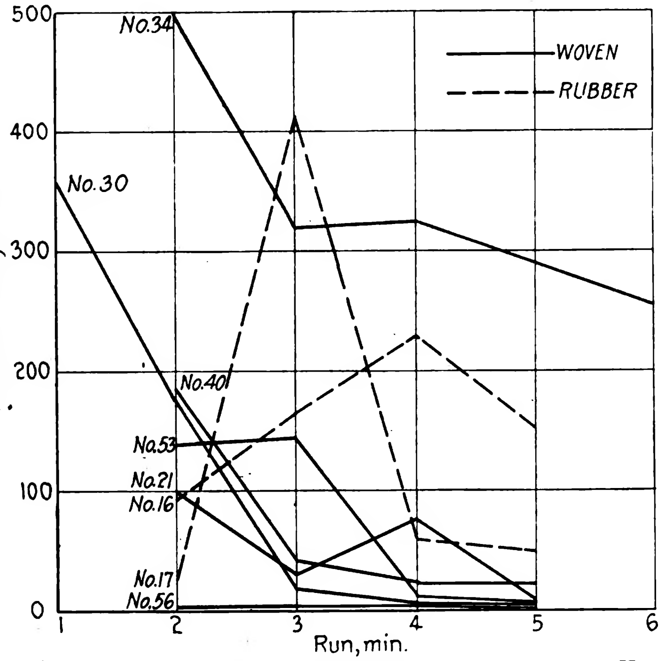


Fig. 21—Results of Tests To Ascertain the Tendency of Hot Lining To Stick to the Drum

Typical results of these tests are shown in Fig. 4 and in Figs. 9 to 12, in some of which the points at which metal imbedded in the linings was first found are marked by the letter *M*. In all the curves a break denotes an interruption of the run. The interruptions occurred regularly at the end of working hours and were due occasionally to cessation of the power supply. Since the adoption of the speed of 600 r.p.m. for the severe-service test with an uncooled drum, this speed has been adhered to in the more recent tests with a cooled drum, on account of the obvious advantages of using the same speed in both cases.

Severe-Service Test With Uncooled Drum

To determine the best conditions for the severe-service test with an uncooled drum as regards speed and power absorption, a considerable number of trials were made with speeds of 300, 400, 600, 800 and 1000 r.p.m., and with power inputs of 4, 5, 6, 7½ and 10 hp. It was found that there was no need for, or advantage gained from, the use of the oscillating device in this test and it has therefore not been used.

The higher power-values at all of the above stated speeds led to very rapid destruction of the samples, and neither the coefficient of friction nor the relative endurance could be established satisfactorily. The combination of 6 hp. and 600 r.p.m. proved to be most satisfactory; it limited the test to a reasonable length of time and brought out the maximum and minimum values of the coefficient of friction found with an uncooled drum. Samples of all available linings were tested at this speed and horsepower and in a number of cases several repeat tests were made with samples of the same lining. As a result, the combination of 6 hp. and 600 r.p.m. has been adopted as satisfactory for this test.

The test is continued until the samples are worn-down to approximately one-half of their original thickness; the length of the curves cannot, however, be taken as a direct measure of relative durability without considering the amount of wear. The majority of the linings required a test-period of from 3 to 7 hr. Only a few showed a running time of less than 1 hr., and these were understood to be experimental types, while the greatest endurance was shown by one lining that was run for 16½ hr. Soon after the load is applied in this test, the impregnating materials soften and burn-out to a varying extent, causing the rapid changes in the coefficient of friction shown in the curves. The condition of the drum at the conclusion of the runs was always good. Sometimes, during the progress of a run, a coating formed on the drum. With some linings this was smooth and seemed to have little effect on the linings. In other cases, however, the coating formed was rough and hastened the destruction of the lining. Figs. 4 to 7 and

Fig. 13 are referred to again, and further results of the severe-service tests are shown in Figs. 16 to 19. At the conclusion of this test, the folded and rubberized linings have usually been found to retain greater stiffness, as shown in Fig. 20.

Determination of Relative Durability

For both the severe-service runs and the tests with a cooled drum, the reduction in both the thickness and the weight was determined. While this information is recorded at the Bureau for reference, it is believed that the user is interested primarily in the thickness loss rather than the weight loss; therefore, it seems preferable to use a wear factor for judging the relative endurance of various linings that shows the relation between the thickness loss and the time, and to disregard the weight loss. Manufacturers may, however, find it useful to record the weight loss as well. The reduction in the thickness is not uniform during the progress of the test, particularly in the severe-service test and, for this reason, measurements are taken at the Bureau during each stop. This is done by measuring the distance between the punch-marks on the pressure-arms by a trammel. To reduce the influence on the wear measurements of uneven contact with the shoe and to some extent also the initial compressibility of the lining, it has been found advisable before beginning the test to raise the tension on the pressure-arms to 150 lb. as shown by the spring-balance. Before each measurement is taken, the tension on the pressure-arms is released and then brought to 50 lb.

In linings of both small and great endurance, the rate of wear may be found to increase or decrease as the test progresses; where the bonding quality of the impregnating compound has been destroyed and a short-stapled fiber has been used, or a rough coating has formed on the drum, the rate of wear during the last part of the run may become very high. These factors necessitate a number of precautions so that fair relative-wear factors can be obtained for different linings, and they contribute also to differences in the results of consecutive tests with several samples of the same lining. In routine tests made by the Bureau three consecutive severe-service tests are being made of each lining to obtain information on the constancy of results, as well as average wear factors. Dividing the thickness loss of one lining sample in inches by the time in minutes gives inconvenient figures and, to avoid this, the decimal point is moved and the following method is adopted:

$$WF = [(C_1 - C_2) \div 10\,T] \cdot 10^6 \qquad (5)$$

where

$(C_1 - C_2) \div 10 =$ thickness loss of one lining as shown earlier

$T =$ total time in minutes

$WF =$ wear factor

Hence

$$WF = [(C_1 - C_2) \div T] \cdot 10^5 \qquad (6)$$

Wear factors for the severe-service test with the samples tested varied from 120 to 2680 for linings understood to be commercial products. Among experimental samples, one was found giving a better wear factor of 82, while a number of others were less favorable and showed wear factors up to 4840. Figs. 16 and 17 show a number of results obtained with representative samples in the severe-service test. Fig. 16 shows several with small endurance, and a group of four with medium endurance; this latter group shows the range in which the majority of commercial linings are found. Fig. 17 shows the results on two linings that were found to have exceptional endurance in the tests. It is interesting to note that, of the samples so far tested at the Bureau, linings of both the woven and the folded and rubberized types were found among those with the smallest and the greatest endurance, although it is understood that the compounds used in the two types are of distinctly different natures. In Figs. 18 and 19, the results of three consecutive tests on each of three different linings are shown. Some variation must be expected from both variability in the lining due to material and workmanship, and factors occurring during the test itself.

Fig. 22—Two Samples of Lining After the Sticking Test

Rivet-Holding Ability

No separate tests were carried out to ascertain the rivet-holding ability of the linings. In any such test the conditions should be similar to those in service. In addition to being riveted to the shoe, the lining should be under pressure between the drum and shoe as in service, and the force used to test the rivet-holding ability should be applied through the drum. A test along the lines of an ordinary tensile-test made away from the drum probably would not be satisfactory.

In all of the work done at the Bureau, there has not been a single case in which the lining separated from the rivets, although at the conclusion of the severe-service test many of the samples were in a very badly worn and limp condition, frequently being worn-down to much less than one-half the original thickness at the entering edge. The riveting is not required to bear any great strain and, if a little care is used in doing the work and attention paid to avoid pulling the ends of the lining from the rivets when mounting the wheels, no trouble need be expected. A special test, therefore, has seemed unnecessary.

In service, brake linings are found to stick occasionally,

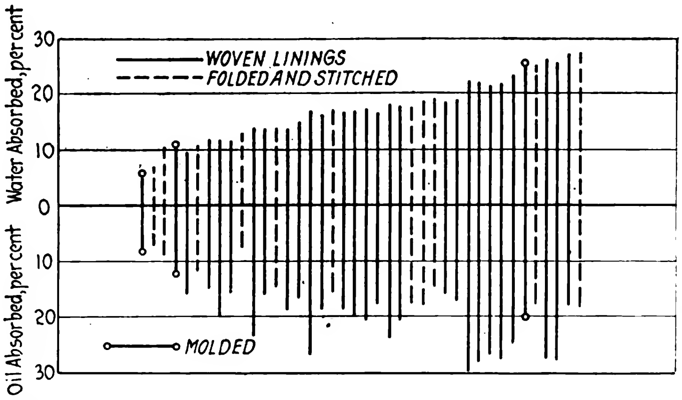


Fig. 23—Relative Absorption of Oil and Water by Brake-Linings

when the brake is left applied to a hot drum. Some car builders have included in their specifications tests to ascertain this tendency that are to be carried out on the car itself, by running a prescribed distance at a fixed speed with the brakes applied. In other cases a test for this tendency has been made by heating samples of lining between metal blocks under pressure and, after cooling, measuring the force required to separate the blocks. This latter method seemed to be less desirable, even for a laboratory test, than one more nearly approaching service conditions. Therefore, standard samples were run in the same manner as for the severe-service test with 6 hp. at 600 r.p.m., for a period sufficient to heat the drum and samples and soften the impregnating compounds. After stopping and cooling, the torque required to move the drum relative to the lining was measured. It was soon found that, with a given lining, the tendency to stick varies with the period of application, and that the period required to develop the maximum tendency varies with different linings. As the heating progresses, the maximum tendency to stick will not result until the compounds have been softened sufficiently. Application of power beyond the point required for the maximum sticking will lead to the changing of the surface layer of the compounds to a dry, powdery or other condition, in which its ability to act as a bond between lining and drum is reduced or lost.

As the nature of the impregnating compounds and their reaction to heating varies, it is understood readily that their relative tendency to stick cannot be ascertained satisfactorily with either of the tests now in use, mentioned previously. This test, as now carried out at the Bureau of Standards, consists in running samples with 6 hp. at 600 r.p.m. for 1, 2, 3, 4 and 5 min. respectively, the load being regulated as promptly as possible after starting; the power is then cut off and the drum allowed to come to rest. The tension between the pressure-arms is increased to 50 lb., as recorded by the spring-balance, and the linings and the drum are allowed to cool for 20 min. The drum is then locked in position by clamping the dynamometer shaft. The torque required to move the brake-shoes in relation to the drum is measured by raising the end of the torque-arm, the force exerted at this point being observed on the spring-balance shown at the right of Fig. 2.

If the pressure on the brake-shoes were released before measuring the torque, the bond between the lining and the drum might be disturbed by the weight of the equipment, the spring of the shoes or accidentally while connecting the lifting device with the torque-arm. To eliminate the effect of this tension, another torque measurement of the force is taken after the bond between the lining and the drum has been broken. The difference between this second torque-value and the first can be used as an indication of the relative tendency to stick. Fig. 21 shows the results obtained with a number of linings. It is noticeable at once that there is a comparatively wide variation in the maximum values found for different linings, as well as in the time at which the maximum occurs. Here, again, it is interesting to note that the folded and rubberized linings as a type, represented by samples Nos. 16 and 17, do not show characteristics distinct from those shown by the woven linings. Fig. 22 is a photograph of two samples of the No. 16 lining shown in Fig. 21. The upper sample showed the maximum sticking for this lining after a 4-min. application; the lower sample had a 2-min. application. The difference in the condition of surface will be noted readily.

Absorption of Water and Oil

Tests to determine the amount of absorption of oil and water were made with samples 5 in. long. After being weighed and measured, they were submerged in oil and water, respectively. The oil or water was heated to 100 deg. cent. (212 deg. fahr.) and kept at this temperature for 1 hr. The samples were then removed, allowed to drain and again weighed and measured.

The liquids were heated to hasten the absorption and thus accelerate the test. The results are shown in Fig. 23 and summarized in Table 2.

TABLE 2—ABSORPTION OF OIL AND WATER

Type of Lining	Absorption, Per Cent Oil	Absorption, Per Cent Water
Woven	14 to 30	10 to 27
Folded and Rubberized	7 to 24	7 to 27
Molded	8 to 17	4 to 24

Measurements to ascertain the change of thickness due to absorption have so far been taken on only a few samples soaked in oil and, where any change was found, it was so small as to indicate that such changes are not likely to cause dragging of brakes having standard linings. In cases where heating may have destroyed the impregnation, the effect may be more marked, but the effect on such linings has not been investigated.

Summary

The work done thus far permits the conclusion that the equipment and general methods developed are satisfactory for laboratory tests to ascertain the relative merits of fabric brake-linings. To establish a suitable test for determining the relative behavior of brake-linings under the more ordinary service conditions where the application of brakes is intermittent and the resultant temperatures are comparatively low, further work is necessary. The severe-service test as used with an uncooled drum is, however, believed to give a fair comparison of the behavior of linings when subjected to severe service. The results obtained indicate very low values of the coefficient of friction as a result of the action of heat on the impregnating compounds.

Very wide differences in the comparative endurance of linings now in use are indicated by the tests, as well as the possibility of marked improvement in durability under severe-service conditions. Owing largely to the users' inability to obtain reliable information of the relative merits of linings otherwise than by prolonged use in actual service, purchases are made almost exclusively on the basis of first cost and without adequate consideration of quality or economy in operation. The general adoption of standard tests, such as have been described, will assist the producer materially in the systematic improvement of his product.

The better understanding by the user of the relative merits of brake-linings, which can be brought about in the same way, will cause an increased demand for the better materials, those giving the most reliable and most economical braking service. The manufacturer will be spared the indignity of having to market materials on the basis of first cost alone, while aware that a relatively slight increase in first cost would permit him to offer materials that will give the user from 50 to 200 per cent more value in braking service.

Chicago and Minneapolis Meetings

IN the month of February two meetings of the Society were held in the Middle West. The first of these was that usually held at Chicago in connection with the automobile show. This took the form of two technical sessions devoted to automotive engineering service subjects on the morning and afternoon of Feb. 1, followed by a dinner in the evening. The other gathering at Minneapolis on Feb. 8 and 9 was the annual Tractor Meeting that is held every year during the week of the National Tractor Show. There were technical sessions on the afternoons of both days and a dinner on the evening of Feb. 9.

The Chicago Service Meeting

The two technical sessions devoted to automotive engineering service subjects held in Chicago, Feb. 1, were the second series of the kind conducted by the Society. They reflected strongly increasing interest in the application of engineering practice to the work of maintaining and operating the world's automotive vehicles and apparatus. It was generally agreed by those in attendance that Engineering Service Meetings should be an annual feature of the Society's work. The scope and complexity of the service industry are increasing daily and the study of its problems will soon be considered equally as important as the other major functions of the automotive engineer. Engineering analysis must be applied to service methods in greater degree. Better tools and practices will have to be created by the men most familiar with motor-vehicle design and construction. The cooperation of the repair superintendent must be sought and closer contact maintained with him by the automotive designer. As stated by President Bachman in opening the Chicago meeting, there should be a better understanding of the operator's problems on the part of the engineer.

The Society's Service Meetings provide an open forum for the mutual discussion of service engineering matters by the constructor and the operator. Careful study of the papers and discussion presented in Chicago last month will reward every progressive designer who aims to have his car or truck render the ultimate in satisfaction to the owner. The first paper of the meeting was presented by B. M. Ikert who chose as his title, A Service-Man's Critical Estimate of Automotive Engineering. He dealt with many specific cases of inaccessibility in current models, slight alteration of which would lighten repair work and reduce labor costs. He called attention to the desirability of studying the design of a new vehicle from the maintenance standpoint in order that the repairs and adjustments made most frequently can be carried out at minimum expense to the car owner. It was the author's opinion that the cars displayed at the 1922 shows reflect more careful thought on features of accessibility and simple adjustment, indicating that designers are more inclined to respect the service-man's desires. In abstracting his paper Mr. Ikert made a plea for the broader education of service engineers and urged the trouble diagnostician to become more familiar with the theory of engine and car performance so that false steps in repairs can be eliminated by better engineering analysis of car troubles.

President Bachman reminded the service-men that the engineer's task is largely one of compromise. He must respect the preferences of the salesman, production engineer, service-man and owner, weighing one against the other and effecting the best compromise in each case. There are bound to be cases where the service-man's request for better accessibility is outweighed by demands for lower production cost. In the opinion of R. B. May a reliable means of studying design changes that facilitate service is to analyze repair parts orders and determine what relation the expense of installation bears to the actual cost of those parts most frequently ordered. It has been his experience that a study of this type reveals many impractical repair operations whose cost could be materially reduced by simple changes in design.

J. Whyte called attention to the lack of standardization in the electric wiring layouts of cars today and urged not only the adoption of a more uniform practice of wiring but also a schematic wire color-standard to simplify electrical repairs. He has found that a closer contact with the repair-man during the early stages of development invariably leads to designs that are most economical from the repair standpoint and cheaper to produce. A. D. T. Libby made an extremely interesting announcement in presenting his discussion, stating that the officers of the Automotive Electrical Association had agreed to stimulate greater use of S. A. E. Electrical Standards in the design of apparatus made by the members of that association.

J. F. Page presented an analysis of the more important organization matters in a modern service-station, which by careful study or by neglect can wholly determine the attitude of the car-owner to that station. While his paper was not of an engineering nature, Mr. Page's reasoning appealed strongly to the members since he presented the views of the man who is in direct contact with the general public. He said that the owner can reasonably demand and expect courteous and intelligent treatment, proper mechanical work, quick service, dependable promises, fair prices and correct and understandable bills. The particular provisions necessary to satisfy these expectations were outlined, the three essential factors being trained personnel, adequate equipment in floor-space and tools and an effective system. Certain unreasonable requests will continue to be made by owners but Mr. Page felt sure that these will be relatively few in number. He stated that the public is fast becoming motor-wise and that the present-day active competition is forcing improvements in accessibility and adjustment with resultant economy in repair costs. Organization of the service-station along business-like lines can no longer be avoided if a company expects to survive in a buyer's-market.

President Bachman believed that Mr. Page's paper made possible a clearer definition of service as "the rendering of facilities for the efficient and economical operation of automotive apparatus." Past-President Beecroft strongly urged greater appreciation of the value of a business man's time when he enters the service-station. The delay he experiences in placing his order or in having simple adjustments made should be reduced to an absolute minimum. Mr. Beecroft reminded those present that the matter of rendering efficient service is becoming more important in the sale of all goods today. It is one of the principal elements in our competing with other nations in foreign markets. Standardization is another important factor, since the use of standard parts

and materials facilitates the servicing of automotive vehicles in distant points without the accumulation of a vast stock of repair parts.

Body Service and Garage Equipment

A paper enumerating the many service advantages resulting from motor-truck body standardization was presented by C. B. Veal and C. M. Manly under the title, Commercial-Body Supply and Service. The authors described a method of constructing motor-truck bodies by assembly from a series of interchangeable standard units and stressed the economies made possible by this departure from the more general practice of designing and building custom bodies to suit the individual whims of the truck owner. These standardized sectional bodies also hold advantages for the dealer and the service-man. Repairs resulting from collision can be made with little delay since complete interchangeable units, such as side-panels and roofs, can be kept in stock and readily assembled into place. A strong plea was made for the adoption of standard body-mounting dimensions by the truck builders as one means of reducing the ultimate ton-mile cost of automotive transportation. J. E. Schipper said that the tremendous stocks of raw and partly fabricated material maintained by body-builders in anticipation of special orders is largely responsible for high body prices. If, through standardization, the body-builder could be assured of a market for a particular body type on many makes of chassis, he could then risk producing to an economical schedule and reduce his overhead and detail costs. J. R. Willis did not believe that the complete standardization of truck chassis body-dimensions is practical on account of the wide variation in weight per cubic foot of various commodities and materials. A truck for hauling empty barrels must necessarily be longer than one hauling an equivalent weight of sand. He felt, however, that all driver-cabs could be made interchangeable between chassis of different makes and capacities; also that spring and wheel locations relative to the frame might follow a uniform practice and simplify body mounting. G. S. Cawthorne said cab standardization is not only feasible but would soon be an established fact. In closing the discussion of the paper Mr. Veal called attention to the existing S. A. E. Recommended Practice for Commercial Body-Mounting Dimensions and urged truck builders to adopt this standard more generally with the idea of lowering the ultimate cost of truck transportation and thereby stimulating truck sales.

H. C. Buffington's paper, The Progress Made in Garage Equipment, served to acquaint the members with a number of specialized tools, including jacks, engine stands and wrecking cranes that are now developed for use in garages and service-stations where lower repair costs are considered. In his opinion this development has only started and the near future will discover a large number of efficient devices for the easier handling of automotive units in process of repair. Mr. Buffington called attention to many points encountered in the design of this garage equipment that warrant special attention on the part of the Standards Committee of the Society. It was brought out in the discussion that car jacks cannot be of the same height for all cars because no provision has been made for the jack-head to be at a uniform distance from the ground. In extreme cases it is not even possible to apply the same jack properly under the front and the rear axle of a given car. Howard Campbell read some discussion he had prepared after a comprehensive survey of garages and service-stations to compare tools, operations and methods. He was surprised at the lack of uniformity in methods pursued by different stations in servicing the same make of car. He predicted that the car builder will soon give as careful consideration to the standardization and design of tools for the repair of his vehicles as he has given to the tools used in car production. Standardized operations, tools and methods lead to standardized service charges and this assures owner satisfaction from the price angle. W. C. Allen stated that $68,000,000 worth of garage equipment had been sold in 1921 and that 40 per cent of this equipment had to be discarded as unfit. This situation indicates, of course, lack of cooperation between the manufacturer of this equipment and the repair-man. It must be corrected by more intimate knowledge of the work to be done by the respective tools and fixtures. One member urged the adoption by all service-stations of a flat-rate charge for periodic lubrication of cars and trucks. The average owner is negligent in the matter of proper draining and refilling of the crankcase, transmission and rear axle, but would take advantage of an oil-while-you-wait service at a reasonable cost.

The general feeling prevailed during both service sessions that automotive repair and maintenance are fast becoming a major function of the industry. In periods of depression the service branch of the business is busier than in times of prosperity. Owners pay more attention to the adjustment, lubrication and care of their cars, for they are anxious to lengthen the life of the vehicles they own and reduce their cost of operation. The growing importance of service work, particularly in its engineering phases, demands that even closer attention be paid to the problems of the repair-man. He can be brought into closer relation with the designer at meetings such as those held in Chicago. It is the intention of the Council and Meetings Committee to enlarge the scope of such meetings to be held by the Society from time to time.

Chicago Dinner

At the dinner on the evening of Feb. 1 President Bachman referred to the sessions held during the day as having given a broader and clearer conception of the engineer's responsibility as to cooperating with other divisions of the industry in assuring that motor vehicles are designed not only in accord with classroom and laboratory theory but to meet the stern requirements of practical use. He appealed to the members to uphold the ideal of service to the end of surmounting quickly the problems of today and the engineer taking his proper place and shouldering his full responsibilities.

Toastmaster Horning said that the industry was facing the same sort of decision that the Generals of the Allies faced in the Battle of the Marne, but that no man can afford to look into the future with eyes of fear. He sounded the signal for dispelling the recent gloom and despair and for going forward with courage to real victory, the psychology of the period being that there is no need for anything but victory ahead.

He quoted the dictionary as defining an engineer as a manager, notwithstanding the casual interrogation, How Can a Man be an Engineer *and* a Manager? He pointed out that occasions like this dinner, at which General Manager Grant, of the Dayton Engineering Laboratories Co., addressed the members in such an informative and inspiring manner, made it possible for the engineers to function in the highest way to accomplish the greatest things in the industry.

The members were very much gratified and encour-

aged by Mr. Grant's remarks, as well as greatly amused by his similes of highbrow production practices. His outline of trade development and vicissitudes during the last decade and his analysis of the industrial outlook, which are reproduced in this issue of THE JOURNAL under the title, How the Engineer Can Help Business, held much of clarity and conviction. It is recommended that the members give careful study to what he said and take home to themselves his admonitions and advice which are undoubtedly very pertinent to the work of all automotive engineering departments. The thing that Mr. Grant emphasized most perhaps is that it is essential that the activities of the financial, production, sales and engineering departments be closely knit together in team-play for the accomplishing of the purposes of the company as a whole, the head of each of these departments having a good working knowledge of the problems of all of the departments.

The World Economic Situation

H. G. Moulton, of the University of Chicago and editor of *Chicago Commerce*, presented some phases of the present business situation from the standpoint of the professional student of political economy and as they appear to the bankers of the world. He said:

European nations, unlike our own, have long been in the habit of making budgets but, unfortunately, since the war they have not been in the habit of balancing them. In the year 1920 not a single nation in Europe, with the exception of Great Britain, was able to balance its budget; every one of those nations spent money far in excess of what they were able to raise from taxation, with the single exception of Great Britain. Even Great Britain in the year 1921 was faced with the inability to raise revenue from taxation sufficient to meet expenditures.

France can raise from taxation somewhere between 18,000,000,000 and 20,000,000,000 francs. The total French expenditures are still running from 45,000,000,000 to 50,000,000,000 francs. In the year 1921 alone the French deficit amounted to 35,000,000,000 francs. In the nations of Central Europe it is a case of printing government paper money, sometimes by the governments themselves, sometimes through the intermediation of the central banks. In other countries it is done on the basis of short-time loans from the banks, and in part on the basis of new bond issues placed in the investment markets. But in any event it means increased borrowing.

After 4 years of war the French debt had increased from 34,000,000,000 to 150,000,000,000 francs, almost quadrupled in the period of the war. It has more than doubled since the Armistice. And yet there are very many writers who tell you that France is coming back to normal conditions with enormously rapid strides. It is the budgetary situation in France, Italy, Belgium, Germany and the nations of Eastern Europe that has given the statesmen of Europe the scare which has led to the calling of an international conference at Genoa.

France sees that she cannot balance her budget out of her own taxation revenues, and therefore insists that she receive reparations from Germany. Meanwhile Germany's budget is more seriously unbalanced than that of France and she insists she cannot pay reparations. Great Britain stands in what may be called a neutral position on the matter at the present time. The Reparations Commission, the allied experts and most of the students of the world have agreed that Germany at the present time cannot pay reparations in very large amounts. The only way in which a nation can pay debts beyond its borders is through exporting goods across its borders. Germany cannot pay with gold. The total gold supply of Germany is less than $250,000,000. That is less than sufficient to pay the indemnity for a single half-year. If, therefore, Germany is to pay, she must pay in goods. But the main truth is that not a single nation is willing to receive the goods with which alone Germany can pay. In other words, all the allied nations themselves, when it comes to a showdown, do not want Germany to pay. Lloyd George stated this officially last winter; Premier Briand stated the same thing in almost identical words, and it is perfectly evident to anybody who will read the facts that that is the case.

TARIFF WALLS

France has raised a protective tariff for the express purpose of keeping German goods out. On the other hand, she would be willing to see some of the German goods shipped into Great Britain to permit Germany to pay reparations to France. But Great Britain has an anti-dumping tariff bill designed specifically to keep German goods out of Great Britain. Both France and Great Britain would be glad to see Germany ship goods to the United States and thus get the means of paying reparations to the Western European countries, but we have an emergency tariff law to keep German goods from inundating our markets and disturbing our domestic conditions. On the part of the United States, those who believe that we really want European debts paid to us and would like to see Germany paying reparations say it is not after all necessary for the United States to receive those goods; that the matter can be accomplished in roundabout ways. Therefore, the goods should be shipped to South America. But the American manufacturers who are looking to South America as their best chance to expand their exports in the face of a declining European demand do not want German competition to drive them out of the South American markets where they have already been obtaining a foothold. So they say, If they cannot sell those German goods in South America to pay reparations, cannot they sell them in Poland, in Czecho-Slovakia, in Russia? That question was propounded by an American economist to a high French official at the time of the Armistice. The reply was, No, France is not willing to see Germany regain her standing in the Eastern European markets. France is looking with eager eyes to the expansion of her own foreign trade in that section of the world.

Russia is out of the question so far as France is concerned, and the United States also is looking to Russia to find an outlet for its excess manufacturing capacity; and the same is true of the great British industries. If they cannot get into Russia, what about Asia, China? When the Celestial Empire comes within the folds of commercial civilization, when that great giant of the East awakens, is that not the place for Germany to sell her goods? In the years before the war there was an international banking consortium for the development of Chinese resources. Five nations, Germany, England, France, the United States and Japan, were in that. Since the war Germany has been excluded. The United States and the other nations involved have become a four-power consortium for the exploitation of those resources.

That is the truth of the matter, as it is recognized in England everywhere. England, therefore, is willing to see the reparations question scrapped. France is hoping against hope that she will save her own financial position by receiving German reparations. On the other hand, England sees that the thing that England needs and the thing that the world needs is a restoration of a prosperous Central Europe. She is looking forward to a restoration of trade with Germany and Central Europe.

We have in place of a powerful and thrifty Germany on the economic side now a decadent Central and

Eastern Europe. In the 44 years between the Franco-Prussian War and the outbreak of the Great War in Europe in 1914 a remarkable development took place in the heart of the Continent of Europe. Germany, until that time, was a weak, poor, agricultural nation, with no great industrial development whatsoever. In the brief space of 44 years there occurred a remarkable economic evolution. That nation advanced from a population of 40,000,000 to a population of 68,000,000. By linking science and industry in a remarkable way the standard of living of those 68,000,000 people was raised to a much higher level than ever before, and Germany not only became a powerful competitor of the other nations in selling goods in the markets of the world, but Germany became by all odds the best market for English goods. Germany, as a matter of fact, exported something like 10,000,000,000 marks worth of goods annually to the rest of the world, but imported 11,000,000,000 marks worth annually from the rest of the world.

CENTRAL EUROPE CONDITIONS

Germany became the organizing force for all the rest of Central, Southeastern and Eastern Europe, from the North Sea to the very borders of Asia. It was from the financial offices of Berlin, Hamburg, Frankfort and Vienna that the vast economic organization of the whole of Central and Eastern Europe radiated. That organization, as the result of the settlements that have followed the war, has been largely broken down. Some of the reasons for this are political and some economic. A unified economic system was treading beyond national bounds. It has been torn down, and a great reduction in the standard of living of the whole region has resulted. Mr. Hoover has estimated that even in Germany the standard of living is now not more than 60 per cent of what it was in the days before the war. It is that situation in Germany, with the lack of purchasing power there, that has compelled England to shift her position with reference to the reparations issue completely. England is opposing the policy of France.

I hold no brief whatsoever for the German political system that existed before the war. I was as glad as anybody to see that broken once and for all, but the situation in Europe now requires us to view it with sanity, because, in the view of the greatest British statesmen, bankers and economists, the very fate of European civilization is at stake in the solution of the problems involved.

POSITION OF THE UNITED STATES

How does that come back to the United States? Mr. Grant told you that our export trade to Europe in the year 1921, as far as agricultural produce is concerned, held up remarkably well. As a matter of fact, the total number of bushels of wheat exported in 1921 was in excess of what it was in 1920. But bear in mind that the price dropped from roughly $2 to $1 a bushel, with the quotations now below prewar levels at the farm. That has given rise to considerable discussion among economists and bankers. I am informed that Europe is willing to take large quantities of wheat, but insists upon getting it at a very low price. There is an extremely sluggish demand. With the Government purchasing power in the field Europe was able to take advantage of the situation at every step and reduce the prices to a level where it could buy. That is the explanation on the demand side. On the other hand, the American farmer pressed relentlessly a huge supply to market all the time, partly because of the necessities of the farmers themselves and partly because of the insistence of bankers that farmers liquidate their loans. On the one side, a tremendous pressure of supply; on the other side, a very halting demand.

If the farmers of the United States cannot sell their grain at a good figure, obviously they cannot buy the same quantity of produce from the local retailers that they would otherwise buy. The local retailer cannot buy the same volume of commodities from the wholesalers of the distributing centers, and of course the wholesalers of the distributing centers cannot buy the same volume of produce from the manufacturers. That means that the manufacturers cannot employ the same number of laborers that they otherwise would, and that those laborers who are out of jobs cannot buy at their local retail stores the same quantity of goods that they otherwise would, and those retail stores cannot pass back the orders to their wholesalers and manufacturers, and so on around the circle. That is perfectly clear and simple.

IMPORTANCE OF EXPORT TRADE

Take the cotton situation. There is practically identically the same thing there. Sometimes people say that the total foreign demand is only 8 or 10 per cent of our total domestic trade and, therefore, we shall not need to worry much even if it disappears. It is over 50 per cent in the case of cotton and roughly over 30 per cent in the case of grain. Let the foreign demand for cotton drop still lower, and the agricultural depression in the South will be more severe. You may recall the "Buy a Bale of Cotton" movement in 1914, at the outbreak of the war when the cotton exports were almost completely eliminated. Cotton dropped to 6 cents per lb. Six cents a pound meant ruin to the cotton industry. It meant inability on the part of the dealers to pay the bills of wholesalers in the centers of the North; it meant inability on the part of the wholesalers in the North to pay their debts to the banks; and so the banks and the business men of Northern cities, instead of trying to drum up more home business, tried to get a "Buy a Bale of Cotton" movement started to raise the price of cotton. What happened when in less than a year the great European demand for cotton reasserted itself and the cotton rose from 6 to 15 and 20 and 42 cents per lb.? Plenty came back to all the Southern region. Not only did they pay off their past bills but they expanded their scale of living; they bought things and developed their farm property in a way never known before. That shows that the United States is linked indissolubly in trade relations to Europe. It is impossible for us to have real prosperity so long as Europe is going in the opposite direction.

THE WORLD AN ECONOMIC UNIT

I agree heartily with what Mr. Grant has said; that it is up to every one of us to do his level best in his own way to improve the situation as he finds it. What can we do with reference to the European situation? We have a foolish notion in the United States that Europe is no concern of ours, that we should live in isolation from the rest of the world, if need be. The plain truth of the matter is that the world is an economic unit now. The farmers of the Country are coming to understand that. The bankers know that the world is an economic unit. Some of these days the irreconcilables in Congress will realize it.

I attended a meeting in New York City last week to consider the question of whether the United States should participate in the Genoa Conference. This is the situation that existed: The United States could not send to the Genoa Conference any official representatives with power to act for it for the simple reason that Congress would not bestow any such authority upon any American representatives. There is no use of our going to the Genoa Conference unless we can join in working out some solution. Every nation has to do its part and take its responsibilities. If we are to have some kind of international organization for the solution of the problems before us, as some of the

European governments now insist, we must have some kind of international economic machinery for dealing with those problems. The duty of the American business-man in 1922 is to recognize that the European problems must find a solution.

DOMESTIC PROGRESS

So far as the domestic situation is concerned, unquestionably we have progressed far in the past 12 months. The progress henceforth, as I see it as an economist, will leave us in a gradually better position, provided the European situation does not grow steadily worse. As manufacturing prices fall toward the level of agricultural prices, there will be a gradual increase in the purchasing power of the farming communities. Many other factors are working toward the same direction. But controlling all is the condition of the European budgets, and the condition of the European budgets will remain what it is, the nations going further and further toward the condition of bankruptcy, until some thoroughgoing, comprehensive, economic program is worked out.

I want to see the United States stand shoulder to shoulder with England in a solution of the problems, because in that I think lies not only the hope of the Anglo-Saxon people in the next 5 or 10 years, but the hope and prosperity of the world as a whole.

MINNEAPOLIS TRACTOR MEETING

Much interest was shown in the meeting of the Society held at Minneapolis during the National Tractor Show Week. The first technical session on Wednesday afternoon, Feb. 8, was devoted to the application of the tractor to the building and maintenance of roads. C. M. Babcock, commissioner of highways of Minnesota, addressed the members and gave some interesting statistical data that indicated the extent of road-building operations in that State during 1921. He urged those present to use their influence to keep the matter of highway construction and maintenance out of politics. Road building is one of the most extensive engineering operations in the United States and it is essential that it be conducted on business-like lines. Each State must interest itself in the road programs of its neighboring States, keep them active in the road-building business and arrange trunk highways with proper relation to interstate transportation. According to Mr. Babcock, only 35 States were able to absorb their share of the Federal-aid fund for road construction in 1921. He fears that this condition may result in a substantial reduction in Federal appropriations for the coming year and presented it as another reason for each State maintaining interest in the road-building activity of the other States.

During 1921 the State of Minnesota expended $33,-656,145 in extending and maintaining its highway system. This fund was raised from State automobile license fees, county and township taxes and the Federal-aid funds. It enabled the State Highway Department to grade 765 miles of road, gravel 497 miles and pave 109 miles. A total of 885 miles was regraveled and 1131 miles was reshaped. The work included the patroling and inspection of 6855 miles of highway. It is readily appreciated how helpful this work is in an agricultural State like Minnesota. The highway funds available did not warrant the expenditure of large sums of money on snow removal. Mr. Babcock said that it is better to let the highways remain somewhat blocked for a few weeks in mid-winter than to spend maintenance funds for snow removal and have the roads go to pieces from lack of proper repairs. The highway dollar in Minnesota is derived from the following sources in the proportions given: County taxes, 32½ cents; township taxes, 20½ cents; motor-vehicle licenses, 16 cents; road bonds, 12 cents; Federal aid, 9 cents; State taxes, 6 cents, and city taxes, 4 cents.

The paper on Operation of Automotive Equipment in Road Construction and Maintenance, given by A. C. Godward, contained some extremely interesting cost data on tractors and trucks operated by the Minneapolis Park Board. Mr. Godward had compiled figures to impress the tractor designers with the value of first-cost of automotive equipment compared with its operation and maintenance expense. His data indicated that first-cost represents only 20 to 30 per cent of the total annual cost of operating a 5-ton truck or a 10-ton track-laying tractor. The ratio of fixed to operating expense was 1 to 2 in the case of the truck, 1 to 3 in the case of the tractor and 1 to 6 in the case of a ¾-yd steam shovel. From these data it can be readily seen how much worth while it is to pay a higher price for new equipment provided its operating and repair expense is reduced by the guarantee of better quality, dependability and ruggedness. Mr. Godward felt sure that automotive designers would always find the road engineer willing and glad to furnish cost information for the guidance of the tractor builder. From his own figures he could define certain development in tractor design that would lessen operating expense and establish the tractor as a more economical unit. It is also the practice of the road engineer to offer suggestions gathered from his field experience and pass them on to the man responsible for the design of the unit he uses. In response to a question, Mr. Godward stated that the cost system he is using had been laid out by his own organization, is adaptable only to reasonably small road operations and probably could not be followed as a standard. In connection with Mr. Godward's statement that tractors in his service work 1600 hr. per year and have a life of 5 years, or an equivalent of 8000 working hr., A. W. Scarratt remarked that, since the average automobile would travel 100,000 miles in this same period, this is an indication of the ruggedness built into the modern tractor. Mr. Godward agreed and attributed the results largely to the excellent care given these machines. They were generally operated on heavy work such as elevating graders, snowplowing and pulling of stumps. In addition to continuous attention to adjustments and lubrication, each machine was thoroughly overhauled in the winter before starting the spring road-work.

The adaptation of the tractor to road-grading work was treated by C. O. Wold. He believes that although the tractor is well suited to the hauling of all sizes of grading machinery, the horse competes strongly with it when the grader-blade width is less than 10 ft. When the work in hand warrants the first expense it is always economical to use tractors with graders of large blade-width; a 12-ft. blade will always build a mile of road at less cost than a 10-ft. blade. This fact is much in favor of the tractor for grader work. In analyzing the sales of grading machinery Mr. Wold said that approximately 2500 machines of the larger sizes are sold annually. All of these machines are for tractor use. On the other hand, 15,000 of the smaller graders are marketed annually, nearly all of them being of the horse-drawn type. The combination of grader and tractor in a single machine did not strike Mr. Wold as being feasible since, at times, it would necessitate the tractor working in the ditch where it might not be stable. A slow tractor speed, about 2 m.p.h., was recommended for this class of work. Although opinion on the proper design of lugs

for tractor wheels varies greatly, Mr. Wold has found the simple cone lug is preferable in road-maintenance work. Tractor wheels should be made heavier for road-work than is the practice in the case of agricultural machines. Answering a question, Mr. Wold said that the recent low cost of horses and feed had reduced the purchase of small tractors for the lighter maintenance work, but that the larger units are still in demand for the heavier duties of road building.

The experience with tractors of a contractor was given by R. C. Shoen in his paper, Practical Road Construction. He applies tractors extensively in his road-building operations and is a confirmed believer in their superiority to horses for this class of work. He employs tractors exclusively on all grading machines. He uses them to transport his camp houses and equipment as the work advances, having found camp mobility a large factor in the reduction of road-construction costs. His tractors have been utilized frequently to move very large boulders that could not be handled with horses; they performed to marked advantage in turning time; and were superior in the finishing operations. The tractors cost $40 per day to operate, compared with $46 for horses doing the same work. Under conditions favorable to the horse, Mr. Schoen found it cost 1½ cents less per cu. yd. to move dirt with the tractor. One of the interesting statements he made was that he adhered strictly to the builder's recommendations on grades of lubricant to be used with the tractors. He attributed a good part of his success to this care in selecting and using good lubricants.

Mr. Schoen pointed out that one automotive link is missing in the road-building business, a suitable machine for hauling dirt where operations are necessarily limited to travel over loose earth. The motor truck is capable of hauling gravel, but in this case all of its travel is over hard surface. One solution of the problem would be the development of a special dump trailer to be hauled by the tractor.

Following Mr. Shoen's address, motion pictures were shown of tractors engaged in road construction and maintenance operations.

At the technical session devoted to agricultural applications of the tractor the first paper, by G. Douglas Jones, was on The Relation of the Tractor to the Farm Implement. Mr. Jones directed the attention of the members to those lines of tractor design development that impressed him as possessing the greatest promise for the future expansion of the tractor industry. He stated that there are 4,000,000 farms in the United States having an individual area of 50 to 200 acres, and that, since these represent 80 per cent of the total number of farms in this country, their owners logically constitute the principal body of tractor buyers. The majority of these farms are operated as producers of diversified crops and a great many types of implement are required to work them. To fulfill the requirements of the farmer raising diversified crops on these smaller farms, it will be necessary to develop small tractors of light weight, capable of handling all of the power work on the farm. They must be adaptable to the cultivation of row crops and not be designed for plowing work only. Although Mr. Jones acknowledged that his specifications represented an ideal, he believed that they pointed the way to the accomplishment of a broader application of tractors to farm work and a consequent expansion and stabilization of the tractor industry. His paper elicited very active discussion. A. W. Scarratt was of the opinion that the concentration of all functions into a single type of tractor is not practicable, and that two types would always be required for farm work, a heavy unit capable of handling plowing operations or other work demanding a rugged machine subjected to heavy drawbar loads, and a lighter machine for harrowing, intertillage work, mowing, binding and belt duty. In reply, Mr. Jones expressed the hope that the plow will be superseded by a far more efficient implement that will make possible more direct application of automotive power to the preparation of the soil. Prof. J. B. Davidson concurred in this hope. He had noticed that there are two schools of tractor designers. One group aims only to replace the horse on the farm and accepts the present-day horse-drawn implement as the final stage of implement development. The other group is studying the possibilities of a more direct application of automotive power to soil tillage, cultivation and harvesting. Professor Davidson has faith in this second group and feels that eventually they will perfect lightweight tractors and implements that are not only more efficient on the farm but more nearly automatic in operation. Frank N. G. Kranich believed that more attention should be given to the operation of farm tractors and implements as single rather than independent units. Replying to Professor Davidson and Mr. Jones, A. W. Scarratt stated that it would be a difficult task to convert the farmer to the use of an implement other than the plow for tilling the soil. Farmers as a class are reluctant to accept any development that tends to revolutionize practices of century-long standing. E. R. Greer suggested that the heavier tractor duties such as plowing might be handled by community-owned tractors of the heavy type, leaving the lighter and diversified work to the all-purpose machine owned and operated by the individual farmers. Professor Davidson said that community ownership of tractors has not proved practical in the majority of cases and is not to be recommended. Contract plowing with tractors is practical, however, and feasible in the scheme suggested by Mr. Greer. Professor Davidson felt certain that a compromise type of tractor can be used successfully, although its power may be slightly inadequate for plowing and excessive cultivation. Such a machine will possess greater utility and be of much value to the farmer of diversified crops. J. S. Clapper also expressed favorable interest in Mr. Jones' ideal tractor. He stated that 45 per cent of the farm land in this country is planted with row crops which represent 55 per cent of the total crop value. It is not possible to convince the diversified-farm owner that a single-purpose heavy-duty tractor is suitable for this work. Present types of tractor are satisfactory for work in the grain fields, but the tractor engineer must establish a closer relation with the row-crop farmer, familiarize himself with the numerous functions this farmer expects his tractor to perform and then perfect an automotive unit that will meet the real need economically.

In the second paper of the Thursday meeting, P. M. Heldt outlined the history of engineering standardization in the automotive industry and urged not only a more extended application of standards in tractor design but a greater interest in the work of creating additional standards in the tractor and farm-power fields. He cited many instances of material savings in production cost effected by the use of S. A. E. Standards in the passenger-car industry. He pointed out the value of S. A. E. Standard steels to the tractor builder, and mentioned the standard magneto mounting as an illustration of passenger-car standards that are applicable to tractor design. Hitches, belt speeds, screw sizes and lug attachments were mentioned as features of tractor design in which stand-

ardization is of value. In closing, Mr. Heldt again urged better cooperation between tractor producers in the extension of the Society's tractor standards as a means of reducing production costs and meeting the demand of the farmer for lower tractor prices. This paper was followed by a general discussion of the S. A. E. Steel Specifications and their application in the construction of farm tractors. Chester S. Moody expressed appreciation of the steel standards but hoped that further investigation would be made of the penetration of heat-treatment in sections exceeding 1½ in. in diameter since these are often encountered in tractor construction. C. F. Clarkson advocated a more thorough understanding of the advantages of standardization between the engineer and those who were his superiors in the executive branch of the business.

Tractor and Plow Reactions to Various Hitches was the subject of a very valuable and interesting paper presented by O. B. Zimmerman and T. G. Sewall. The authors had made an analytical study of the forces and reactions in effect when single and multiple plows are being drawn by a tractor. Formulas were derived that are readily applicable to the solution of problems of tractor stability against overturning. Using the methods developed in the analysis, it is possible to find more readily the answer to such questions as: Shall the tractor be run on the land or with one wheel in the furrow? Should the tractor hitch be low or high in relation to the ground? Where is the center of plow reaction? The reaction of the plow to forward motion is resolved into three major components: one across the furrow; another down the furrow; and the third the vertical force. These in turn are considered as acting at one point that the authors designate as the center of plow reaction. The effect of varying the direction of the line of draft through this point is studied in a way that shows the necessity of exercising care in the selection of a common hitch-point for the draft of multiple-plow units. Diagrams and tables are given that enable the engineer to determine whether long or short hitches are desirable in a given case and what relation the hitch center should bear to the center of plow reaction. It is shown, for example, that if the tractor is operated on the land in preference to the furrow, a long hitch is desirable with two and three-plow units. The forces that tend to overturn the tractor are carefully analyzed and the effect of engine torque, drawbar reactions, rolling resistance, slippage of drive-wheels, gradient and weight of operator is clearly pointed out. Two representative tractors reported in the Nebraska tests are compared for stability by the use of the formulas developed in the paper. Stability curves are constructed for each of these machines showing their relative tendency to overturn under the same operating conditions. Mr. Zimmerman stated that while the analysis might be more closely and correctly refined, the main features developed clarify and segregate the primary influences affecting the several actions and reactions, whose net sum might be approximately ascertained under any set of conditions, by applying the simple formulas given. The analysis set forth also establishes a definite method of attack for a more correct determination of the most suitable hitch and the selection of proper wheel lugs.

The Dinner

O. W. Young, second vice-president of the Society for tractor engineering, presided at the dinner held at the Hotel Radisson. E. A. Merrill, who was toastmaster, introduced in a highly felicitous manner the speakers of the evening, the first of whom was E. G. Quamme, president of the Federal Land Bank of St. Paul, Minn.

Mr. Quamme said in part:

> The agricultural industry of the United States, which is our foundation industry, is in a bad way and has been for 2 years. Two things have contributed largely to disorganizing it, the first being the rapid and drastic decline in prices of farm products, and the second the inflation that entered into land values. Many who have studied the situation carefully have thought all along that it was a great mistake to deflate the value of farm products so drastically and so rapidly. It would have been better for our Country if we had moved a little more slowly, for the American farmer and the villager constitute the best market that American industry has. While they constitute only 37 per cent of the population, they purchase fully 60 per cent of all the manufactured products sold in this Country.
>
> When there is a mortgage of $100 an acre bearing 7 per cent interest, there is a charge of $7 per acre on that land that must be paid before anything else is paid. While inflation entered into land values, it entered also into governmental costs, school districts, townships, counties, State government, until the taxes had gone up from $40 per farm of 160 acres to as high as $3 an acre, or $480 per quarter-section. Twenty years ago $3 per acre was considered good rent for a farm.
>
> The gross producing power of this Nation is $40,000,000,000 a year. If our governmental costs are $4,000,000,000, one-tenth of the gross earning power of the entire Nation is used for governmental purposes. We do not realize the full importance of this yet, but we will as time goes on.
>
> After the war of 1812 we had a down-curve, as all of you who have studied economics know, for 30 years. After the Civil War we had a down-curve of 30 years and an up-curve of 20. In times of peace and when there is no obstruction on the part of the government or otherwise by regulation, there is a relative value between all things, between the bushel of wheat and the monkey-wrench, and the bushel of wheat and any other article. That relation has now been thrown out-of-joint; it does not exist. Food products, farm products and raw materials have been deflated down to the rock-bottom, below anything that we have seen in the last two decades and much below the cost of production.
>
> Our industry has been developed to such a point that if it is operated at 60-per cent efficiency it will satisfy all the needs of our Country. If it is to be operated at 100-per cent efficiency we must find a foreign market for 40 per cent of our products. Agriculture also has been efficiently organized and developed. We do not need 80 per cent of the efficiency that the agricultural production in this Country has attained to feed our Nation. If it is to operate 100 per cent., we must find export for over 20 per cent of our products.
>
> From 1910 to 1920 the farm-mortgage indebtedness of the United States increased 137 per cent. The farm values, including both land and improvement, increased only 117 per cent. The mortgage indebtedness of the United States in the last 10 years increased much faster than the wealth and the population. In other words, we were mortgaging the future. Much of the increases in value during 1916 and the four following years were fictitious, not being based upon income.
>
> AGRICULTURAL AND FINANCIAL SITUATION IMPROVING
>
> The agricultural situation today is not so bad; it is rather hopeful and much better than it was last year or the year before. We are past the worst. The worst period we have left is that between this and harvest time. We need cooperation and coordination of effort on the part of all citizens and all classes to carry

through until we get a crop. Then we will be on the uptrend and will have seen the worst.

As to how long it will take to readjust, bring the crops back again in regard to all things, I think it will take at least 20 years, but we will learn to adjust ourselves to these conditions and the worst will be over. Industry will be operated not on a 100-per cent basis but will start after a while on a 20, 30, 40 and 50-per cent basis, and so on, and if we can find more markets we can extend our operations.

The financial situation is improving wonderfully. It began to improve in the East. Reserves are getting into good shape. There has been good liquidation. We have laid a solid foundation so far as financing is concerned. It is the best that we have had in many years, and is getting better every month. There is a good demand for mortgages, which will help to stabilize the agricultural situation.

It was absolutely wrong for the Government to encourage the counties, the States and all public subdivisions to build courthouses, schoolhouses and the like at the time the war ended, when we needed capital and material and did not have labor enough to go around. Many people said at the time, "For heaven's sake, when we cannot find enough labor for essential industry, let us not inject this political and public work; let us save it so that if hard times come later on, we will have it." We have created billions of dollars of tax-free securities and spent the money lavishly and foolishly. Now is the time to stop and safeguard what capital we have left for industry.

The automotive industry is one of the largest industries in this Country and one of the largest in the world, but I believe that it was overdone.

FREIGHT RATES AND COAL PRICES

What are the two main things that stand in the way of immediate resumption of business? They are railroad freight-rates and the price of coal. We have always thought very highly of our wheat crop in Minnesota; when people of the East think of Minnesota, they think of the wheat crop. It is important, of course, but it is not one of our greatest crops. Last year we sold about $170,000,000 worth of butter. Our wheat crop amounted to about $30,000,000. This season we bought $30,000,000 worth of coal in Minnesota. With the present price of coal we have to trade off our magnificent wheat crop in this State to have fuel for 1 year. Necessity, the mother of invention, drives people to many things. It will drive us to using lignite coal mined in North Dakota and Montana. Processes are already under way that will prepare that coal for producing iron ore and for every other useful thing that requires grate fuel. It will not be long until we can declare our independence of Pennsylvania and West Virginia.

Our railroad division points were laid out on the basis of a 10-hr. day. A train would run so far in 10 hr. Then there came the 8-hr. day on the railroads. This necessitated extra crews, time and overtime, time-and-a-half, and pay-and-a-half for time-and-a-half. Unless the freight rates are readjusted, the whole industrial map of the United States will be changed. Large areas of territory will be depopulated. There are manufacturers in New England who cannot afford to stay there any longer because they have to ship their products into the interior of the Country. The food supply comes from the interior, and it costs so much to send it to these people that they cannot afford to pay wages high enough to continue in business, maintaining the high standard of living that their employes are entitled to as American citizens. It will be better and cheaper for us, if necessary, to subsidize the railroads, and make them go back again to their freight charges of 1912, 1913 and 1914.

J. L. Record, chairman of the board of directors of the Minneapolis Steel and Machinery Co., gave a comprehensive analysis of general business conditions, saying in part:

While the agricultural situation in the corn-producing States is exceptionally bad, there are other localities where it is exceptionally good. In California they have never experienced such prosperity as now. In the vineyard sections they have produced wonderful crops and sold them at prices never heard of before.

RECOVERY IN WHEAT-PRODUCING TERRITORY

In some of the cotton-producing territory where crops were fairly good and harvested early and prices were fair, there is a substantial start toward recovery. The wheat-growing sections of the Middle West, while subjected to a decrease in the price of their products, have not suffered much from the decline in the value of the farms because there has been there little inflation of values. One crop in that territory with a good fair price will see it well on its way to recovery. I believe we shall have satisfactory business from this territory very much sooner than from the corn-producing sections.

Reliable information comes to us from the East indicating that the situation there is improving steadily; because of its diversified farming this territory did not suffer to the same extent as the West, and satisfactory conditions will prevail soon. This advice comes direct from the tractor and implement dealers. Trade is fairly satisfactory in the East now.

Taking the agricultural situation over the Country as a whole, there is nothing about which the farmer or the community should be greatly discouraged. That recovery will take some little time there is no question, but that there will be recovery, and much more quickly than most of us think, there is not the slightest doubt in my mind. There is no class that can buckle down and work harder than the farmers. No industry that I have ever been connected with has the recuperative powers of agriculture. When it comes to getting back to normal, whatever that word may mean, I believe the agriculturist will be very nearly at the head of the procession, if not at the head.

We are not suffering so much from a depression in agriculture as from the result of too much prosperity during the war period. The agricultural industry itself is all right. Some of those engaged in it are hurt but they will recover, or others will take their place. It is the same in manufacturing; somebody else will build tractors if we do not. I have never seen any satisfactory general business condition or situation except when the railroads were prosperous and in the market for their normal supplies.

THE ARGENTINE AND OTHER COMPETITORS

In the Argentine, which is our principal competitor in grain production, the average rail-haul from all of the grain-producing sections to the ocean is less than 200 miles. The same thing is true of Uruguay and of Southern Brazil. A glance at the map of South Africa indicates that the haul is no greater there. The grain produced in the Upper Mississippi Valley, in Iowa, Minnesota, the Dakotas and parts of other States, must be carried to our Great Lakes ports, a distance that averages from 300 to 500 miles; and from the Lake ports it is 1500 miles to tidewater. We have maintained our place in the markets of the world, but the changed and changing conditions of transportation and handling will make it more and more difficult for us to compete if the present transportation rates continue.

In the prewar period our freight rates were very

(Concluded on page 221)

Manifold Vaporization and Exhaust-Gas Temperatures

By O. C. BERRY[1] AND C. S. KEGERREIS[2]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

STATING that present internal-combustion engine fuel is too low in volatility for economical use and that this is the cause of engine-maintenance troubles, the authors believe that, since it is not possible to obtain the more volatile grades in sufficient quantity, the only hope of remedying this condition is to learn how to use the heavy fuel, and that the most promising method of doing this lies in the effective use of heat.

As the experimental data regarding the best temperature at which to maintain the metal in a hot-spot manifold and the range of temperatures available in the exhaust gases, are meager, the authors experimented in the Purdue University laboratory to secure additional data. They present a summary of the results. They feel that the exhaust-gas temperatures are high enough so that properly designed manifolds, together with thermostatically controlled carbureter temperatures, should make possible the satisfactory carburetion of fuels considerably heavier than the present "power" gasoline, without seriously limiting the power, efficiency or flexibility of passenger-car engines or causing any engine-maintenance troubles.

THE present fuel situation is one calling for serious thought. Internal-combustion-engine fuel is so low in volatility that it is not being utilized economically. A large number of maintenance difficulties can be attributed to the low volatility of the fuel. The petroleum reserves cannot be increased and, even granting a liberal use of substitute fuels, we can scarcely expect the time to arrive when the refiner will be willing to return to a fuel of higher volatility. Therefore, our only hope of progress is to learn how to use the heavy fuel. A first-class solution of this problem might go so far as to make possible the use of still more of the heavy ends, enable us to get more out of each gallon of fuel and decrease the operating difficulties, thus constituting a real step in progress.

A considerable portion of our present grade of engine fuel passes through the intake-manifolds of automobile engines in liquid form. It is difficult to design a manifold that will distribute uniformly to all of the cylinders this liquid portion of the mixture furnished by the carbureter. No matter what condition the fuel is in when it reaches the cylinder, it must be vaporized before it can be burned. The most effective way yet found of improving distribution and combustion is to apply heat in some form or other. This makes it valuable to know how much heat to introduce and how to introduce it to get the best results.

One of the commonly used methods of heating the mixture is to have portions of the metal in the intake-manifold heated by the exhaust gases. The liquid fuel in the manifold tends to flow along the walls; therefore, it will come in contact with these hot portions and be flashed into a vapor. A considerable portion of the liquid is thrown out of the mixture at the carbureter throttle-valve and onto the walls immediately above the throttle. This liquid tends to cling to the walls. At very low air velocities, as when the engine is idling very slowly, it will often collect in a puddle immediately above the throttle, especially when the manifold has a long vertical section at that point. At higher air-velocities this liquid will rise through the vertical section of the manifold and collect at the bottom of the horizontal sections. The manifold is swept clean continuously of these liquid-fuel puddles only at comparatively high air-velocities. Still other portions of the liquid fuel tend to collect wherever the direction of the flow changes, or wherever there are eddy currents due to any other cause. Therefore, the ideal condition for drying the mixture would be to have the metal heated at these points, especially on the outside walls at the bends and at the vertical section just above the throttle. These heated portions of the intake-manifold are called "hot-spots."

It is claimed for this hot-spot method that it produces a mixture sufficiently dry without heating it as much as is necessary in the "heated-air" method. The ideal hot-spot manifold would accordingly be one that produced a mixture dry enough to distribute evenly and burn well in the cylinders, with the least possible heating of the mixture itself. Some hot-spot arrangements allow the whole mixture to come into contact with the hot metal, and consequently operate by heating the whole mixture. Others are arranged to keep the gases away from the hot metal as much as possible, while the liquid portions of the fuel are brought into contact with it and are vaporized. Such manifolds operate principally by heating the fuel itself after it has been metered.

The Society of Automotive Engineers appointed a special committee in 1919 to study the problems involved in the use of present internal-combustion-engine fuels. H. L. Horning served as chairman of this committee, and a careful study was made of the whole situation under his direction. The committee felt that the hot-spot manifold offered the most promising means of alleviating the difficulties encountered in carbureting the present engine fuels. Therefore, it made an exhaustive report on the present state of the art of designing hot-spot manifolds. This was presented to the Society and published in THE JOURNAL.[3]

In this report, however, as in the other literature on the subject, there is a lack of experimental data showing the optimum temperature at which to maintain the metal in the hot-spot, and the range of temperatures available in the exhaust gases of an engine under different running conditions. This information is fundamental in designing and perfecting any particular hot-spot manifold. Tests have therefore been carried out in the laboratories of Purdue University to obtain this informa-

[1] M.S.A.E.—Chief engineer, Wheeler-Schebler Carburetor Co., Indianapolis.

[2] Jun. S.A.E.—Assistant in carburetion research, Purdue University Engineering Experiment Station, Lafayette, Ind.

[3] See THE JOURNAL, July, 1920, p. 25.

tion. These tests were divided into two groups. The first deals with the optimum temperatures in the metal in the hot-spot; the second, with temperatures available in the exhaust gases, together with the factors influencing these temperatures. A complete report of these tests is contained in a bulletin published by the Purdue Engineering Experiment Station, entitled The Hot-Spot and Factors Affecting the Exhaust-Gas Temperatures. The present paper is presented through the courtesy of the Purdue Engineering Experiment Station and gives the general conclusions of the bulletin in an abbreviated form.

Hot-Plate Tests

Before a hot-spot manifold is designed for any fuel, it is well to determine the following three points:

(1) The rate of vaporization per unit of area for different temperatures
(2) The best temperature of the hot-spot for the vaporization of the fuel
(3) The cracking point of the fuel and the deposition of solid matter

This information will provide a foundation on which practical designs can be based for any hydrocarbon fuel.

Fig. 1 gives a general view of the apparatus used in the tests mentioned. An iron plate 5/8 in. thick, 4 in. wide and 8 in. long was placed over an electrical heating element and packed in a box filled with asbestos, at *A* in Fig. 1. A well *B*, 1.015 in. in diameter and 0.128 in. deep, was located at the top center of the plate. Two thermometer wells were drilled on each side of the plate, one of each pair being as close as possible to the vaporizing well and the others farther away to give the plate temperature at a point where there was little or no flow of heat. The heat was regulated by a salt-water rheostat, *C*, in series with the heating coil, ammeter and switch. The vaporized fuel was carried away through a hood over the plate connecting with an 8-in. vertical pipe. The gasoline was weighed on a small chemist's balance, the fuel being siphoned from a beaker on the scale through a small copper tube to a point 1/2 in. above the top of the well. This prevented any portion from touching the liquid or interfering with the vaporization. The flow of fuel was regulated by a needle-valve, placed in the line just outside of the hood. The temperatures were measured by 950 deg. fahr. nitrogen-filled mercurial thermometers, accurate to within 5 deg. at the extreme conditions. The time of each test was taken with a manually operated stop-watch.

Fig. 1—General View of the Apparatus Used in Making the Tests

A portion of the fuel was thrown out over the edge when the first well, which was shallow, was used; consequently, too high a rate of vaporization per unit area was indicated. Therefore, in the later tests the vaporizing well was made deeper by welding additional metal around the top. When machined, this gave a well of 1.051-in. diameter and 0.610-in. depth. In this well too low a rate of vaporization was indicated. The reason for this is that the iron forming the upper part of the well was considerably farther away from the heating element than the thermometers and was consequently considerably below them in temperature. This resulted in a decreased vaporization from these upper portions. The entire wetted area was measured as the vaporizing surface; so the average rate of vaporization was lower than it would have been had the entire surface been at the temperature indicated by the thermometers. Since the results obtained from the first well tended to be too high, and those from the deeper well too low, an average between the two will represent nearly the real truth. In plotting the curves and reporting the results of these tests, the average figures are used.

The apparatus is liable to a few errors that can be eliminated by calibration. They are errors due to siphoning and the evaporation from the surface of the fuel in the beaker. The siphoning error is small and equal to the weight of gasoline displaced by the fuel-pipe between the initial and final levels of the fuel in the beaker, the pipe being considered as a solid. The error is 0.88 per cent for the individual beaker and pipe, and was corrected in the computation of the tests. The largest error is the evaporation from the surface of the fuel in the beaker. This is especially large for the lighter gasolines. This evaporation will vary according to the saturation of the air in the scale box. The temperature of the air above the beaker was recorded for each series of tests and from calibration tests this error was corrected with a considerable degree of accuracy.

Fuels Tested

One kerosene and three gasoline samples were tested. The specific gravity and distillation data are shown in Table 1. These fuels were obtained directly from a refinery through the courtesy of one of the leading manufacturers of petroleum fuels.

The distillation curve of a fuel is very valuable because the temperatures at which the fractions distill are the criteria by which comparisons of different fuels for volatility should be made. The specific gravity is a very uncertain indication of quality, because several combinations of petroleum fractions may have the same specific gravity and yet be wholly different fuels. The end-points and boiling temperatures of the fractions determine the character of the fuel more than the specific gravity.

The results of the tests are shown in Fig. 2, which gives the curve for each of the fuels tested. In these

TABLE 1—SPECIFIC GRAVITY AND DISTILLATION DATA OF FUELS TESTED

Percentage Distilled Off	Baumé Gravity of Fuel, deg.			
	70.0	64.2	56.5	41.5
Initial boiling point	97	120	96	346
10	127	155	162	386
20	143	169	210	400
30	155	179	247	408
40	165	187	272	413
50	176	196	295	424
60	187	205	313	432
70	193	215	335	440
80	206	227	356	452
90	225	245	381	476
Maximum	300	312	425	524

curves the temperature is plotted horizontally in fahrenheit degrees; vertically the time in minutes required to vaporize 0.01 lb. of fuel per sq. in. of hot surface is shown. The temperatures are in all cases those indicated by the thermometers nearest to the hot-spot in the hot plate. They represent 70.0-deg. high-test gasoline, 64.2-deg. domestic aviation gasoline, 56.5-deg. commercial power gasoline and 41.5-deg. kerosene, as shown on the Baumé scale. The curves are similar in general characteristics, the difference being that increasingly high temperatures are necessary to vaporize the less volatile fuels.

It was necessary to hold the temperature constant and continue the evaporation for a considerable length of time before each test was started. When the fresh gasoline was first introduced into the hot well, its rate of vaporization was rather high, the more volatile portions evaporating and leaving the heavier parts as a comparatively inert mass in the hot well. After a time, however, a state of equilibrium would be reached, when the fumes leaving the hot well would contain the same percentages of the lighter and heavier fractions as the original gasoline, and the proper rates of vaporization would be reported.

The fuel showed evidences of cracking during the period of rapid boiling, and a deposit of solid matter was left on the edges of the well. The two lighter gasolines, 70.0 and 64.2 deg. Baumé, left a deposit that resembled paraffin, while the deposit from the heavier gasoline and the kerosene had more the appearance of tar or carbon. When the liquid film was allowed to seep over the edge of the well these deposits were dissolved and carried out with the vapor. This vapor afterward redeposited some of the solid matter in the hood behind the well. When the spheroidal state was reached, the deposition of solid matter ceased entirely. This is very important to the designer of a hot-spot manifold. The temperatures that cause a deposition of solid matter are rather limited in extent and are entirely below those that will throw the fuel into the spheroidal state. The very high temperatures are not the ones that cause the clogging of the manifold.

The appearance of the vapor under different conditions was interesting. When the liquid was boiling from a wetted surface the vapor was very wet and condensed easily. In fact, its appearance as it was carried to the rear of the hood was that of a dense fog. In the spheroidal state, the vapor was dry and almost invisible; so that, even after it had traveled a few feet in a cool pipe, no appreciable condensation was noticed.

The curves in Fig. 2 show that the effectiveness of the hot-spot drops off very rapidly at the lower end of the temperature range. A similar curve for the fuel to be used will show the lowest temperature that it will pay to use with that fuel. It is not wise to attempt to make use of the highest rate of vaporization for two reasons. The temperature range is too narrow and this is where cracking and deposition of solid matter takes place. It is better to use the higher temperatures that produce the spheroidal state. After the spheroidal state is once reached, an increase in temperature does not make any very great change in the rate of vaporization. The metal in the hot plate was often red-hot during these tests, but at no time were the fumes from the hot-spot ignited by the plate when the latter was below 1425 deg. fahr. This makes it practicable to use a very wide range of temperatures in the metal of a hot-spot, and eliminates the necessity of using a thermostat.

Exhaust-Gas Temperature Tests

The second group of tests was intended to determine the exhaust-gas temperature of an automobile engine under different running conditions. Some very careful work had been done previously by several investigators to determine these temperatures under specific running conditions, but little attention had been given to the factors influencing them. The more important of these factors are as follows:

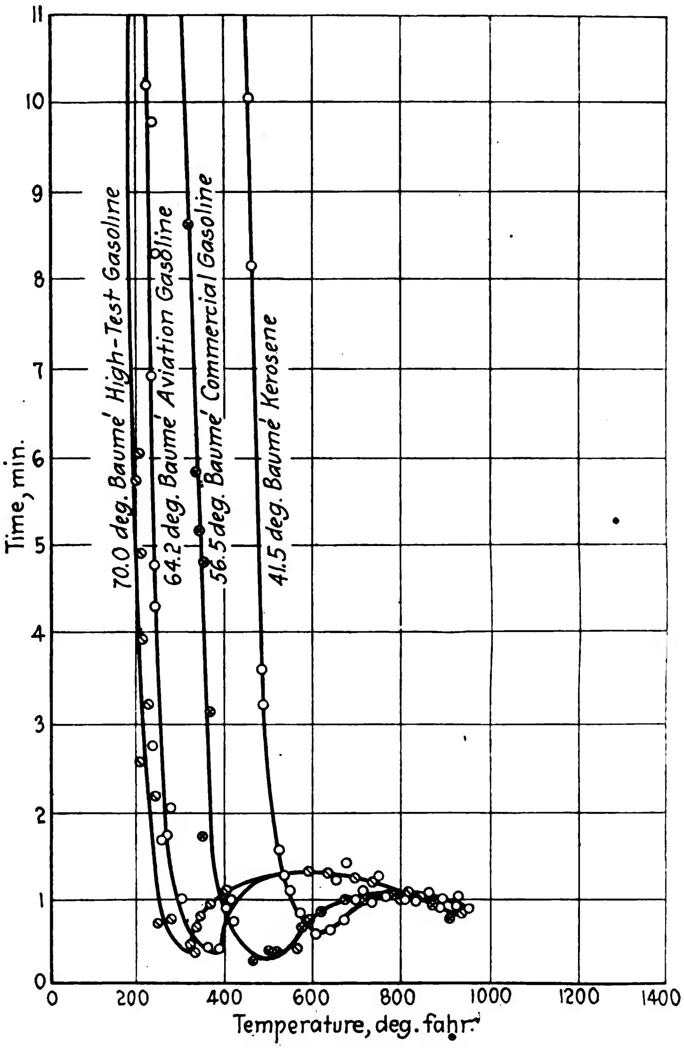


Fig. 2—Curves Giving Results of Fuel Tests on Kerosene and Three Grades of Gasoline

FIG. 3—THE SIX-CYLINDER ENGINE USED IN MAKING THE TESTS WAS MOUNTED ON A TEST-BLOCK AND CONNECTED TO AN ELECTRIC DYNAMOMETER

(1) Temperature of the cooling water
(2) Temperature of the inlet air
(3) Timing of the spark
(4) Richness of the fuel mixture
(5) Speed of the engine
(6) Load carried by the engine

Therefore, tests were carried out to determine the effect of each of these factors on the temperature of the exhaust gases. The apparatus used was an Oakland-Northway six-cylinder engine having a 2 13/16-in. bore and a 4¾-in. stroke, mounted on the test-block and connected to a Diehl electric dynamometer as shown in Fig. 3. Two manifolds were used, designated as manifolds *A* and *B*. Manifold *A* had the early conventional type of hot-spot formed by passing a very small portion of the exhaust gases around the exterior of the three headers of the intake-manifold. Manifold *B* had the intake cast on top of the exhaust and enough contact between the two headers to cause considerable flow of heat. These were interchanged for some of the tests. The air was measured by an Emco No. 4 diaphragm meter reading to cubic feet, the dial being arranged so that an accurate estimation to tenths was possible. The gasoline was siphoned from a 2-liter beaker on a large chemists's balance. The speed was measured by a tachometer on the dynamometer and verified by the stop-watch and revolution-counter readings. The watch, the revolution

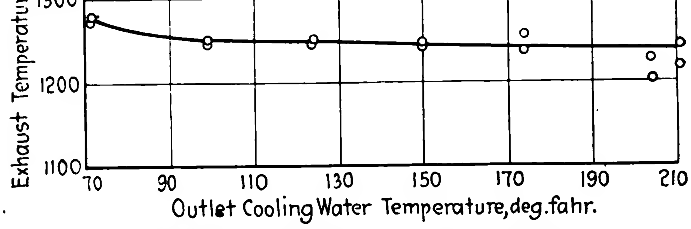


FIG. 4—THE EFFECT OF THE TEMPERATURE OF THE COOLING WATER ON THE EXHAUST TEMPERATURE IS RATHER SMALL

counter and the air meter were electrically controlled by the scales, to start and stop the measurement of these quantities at the same instant. The air was heated to any temperature desired by a gas-heater that could be regulated by controlling the gas-burners. All temperatures, such as those of the inlet air, and the cooling water, and all the hygrometer readings, were measured with mercurial thermometers; the exhaust-gas temperatures were measured with iron-constantin thermocouples,

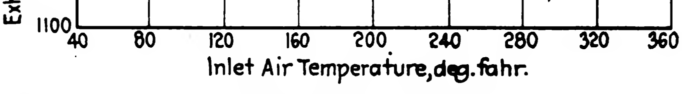


FIG. 5—CURVE SHOWING THE EFFECT OF CHANGING THE TEMPERATURE OF THE AIR ENTERING THE CARBURETER

and these were calibrated carefully. These thermocouples were placed near the outlet end of the exhaust manifold. The manifold was drilled and the couples allowed to extend a little more than half-way through the passageway. The couples were not covered, thus allowing the gases to come directly in contact with them, and the point where they entered the manifold was packed with asbestos, to prevent them from being cooled by the manifold walls. The temperatures reported, therefore, represent the actual temperature of the gases at the point where they would be most likely to be used in producing a hot-spot.

The tests to show the effects on the exhaust temperature of the temperature of the cooling water and of the inlet air, the timing of the ignition and the richness of the fuel mixture were all run at one-half load at an en-

gine speed of 1000 r.p.m., holding all of the running conditions constant except the one to be tested. The engine was allowed to run under test conditions for a considerable length of time until all of the temperatures had come to an equilibrium before each test was started.

The temperature of the cooling water was varied between 70 and 212 deg. fahr., the tests being run at one-half load, at 1000 r.p.m. The results are represented graphically by the curve in Fig. 4. Contrary to what might be expected, the effect is shown to be rather small,

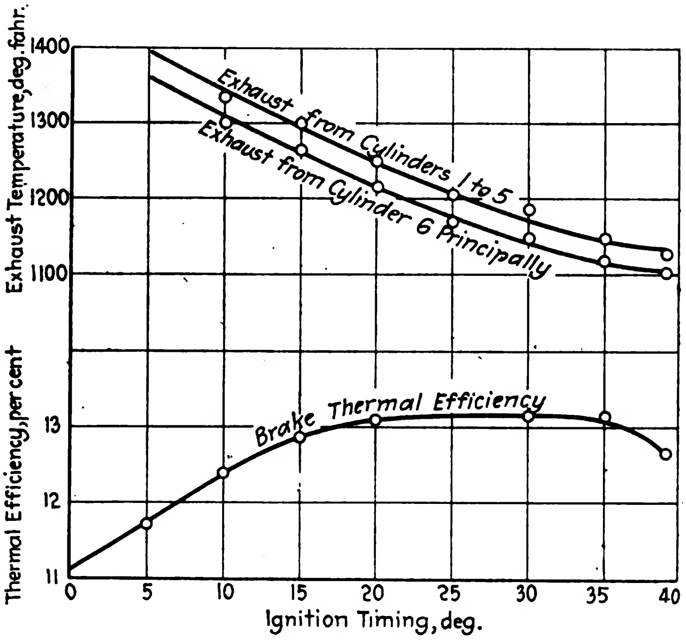


FIG. 6—THE EFFECT OF CHANGING THE SPARK-TIMING ON THE EXHAUST TEMPERATURE AND THE BRAKE THERMAL EFFICIENCY

and heating the engine produces a slightly lower exhaust-gas temperature.

Two series of tests at one-half load, at 1000 r.p.m., were run to determine the effect of changing the inlet-air temperature, this being varied between 59 and 335 deg. fahr. The results are shown in Fig. 5. The peculiar shape of the curve can possibly be explained by saying that the 59-deg. air probably did not enable the engine to burn all of the fuel. As the temperature increased to about 80 deg. fahr., the combustion became complete and, since it was so very slow, the loss of temperature due to radiation and work were at a minimum and the exhaust-gas temperatures were at a maximum. During the period between 80 and 160 deg. fahr. the vaporization of the fuel improved very rapidly, the combustion became more and more rapid until it was complete at the begin-

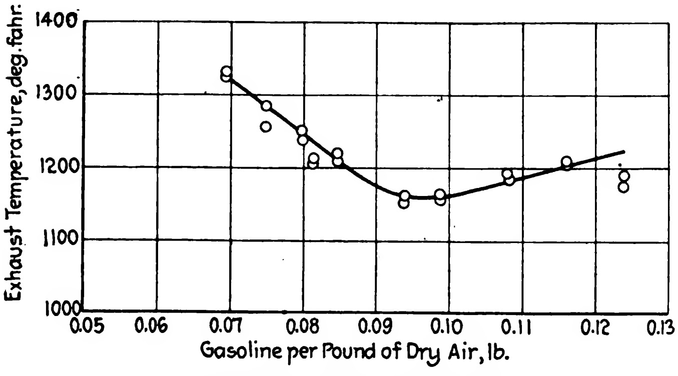


FIG. 7—HOW CHANGES IN THE FUEL-AIR RATIO AFFECT THE EXHAUST TEMPERATURE

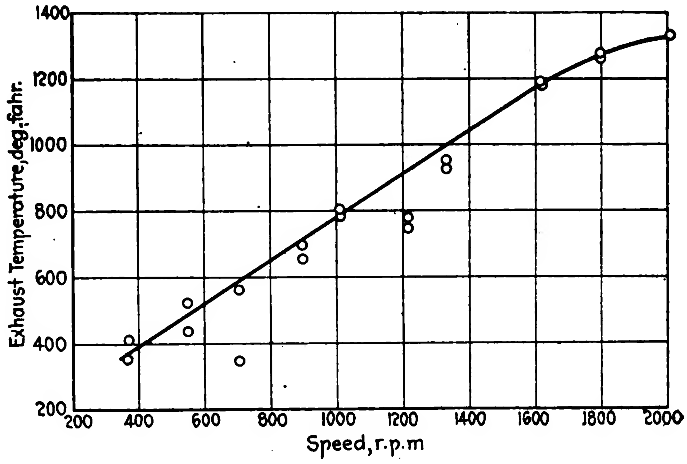


FIG. 8—RELATION BETWEEN CHANGES IN SPEED AT LOW LOAD AND THE EXHAUST-GAS TEMPERATURE

ning of the working stroke, the loss of temperature due to radiation and useful work reached a maximum, and the heat left in the gases at the time they were exhausted from the cylinder decreased rapidly. The decrease in the exhaust temperature above an inlet temperature of 160 deg. fahr. was not so pronounced, since an increase in the rate of combustion beyond the point where it was complete before the beginning of the working stroke could not have very much effect.

The effect of changing the spark-timing was studied with the engine running at one-half load, at 1000 r.p.m. The tests showed that advancing the spark reduced the exhaust temperature, but that the effect is not large. Fig. 6 shows the results graphically.

The effect of changing the fuel-air ratio was checked

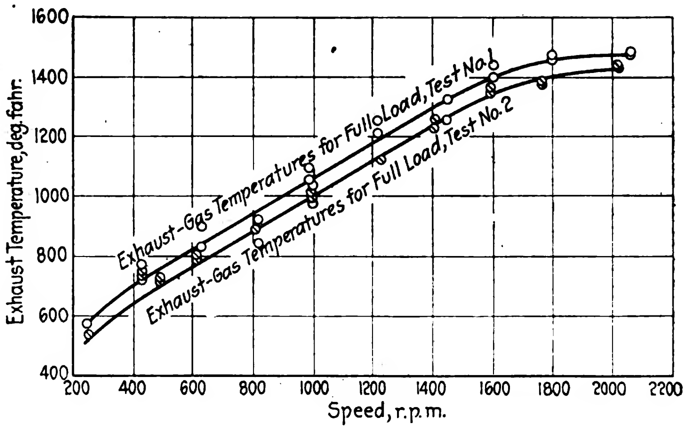


FIG. 9—RELATION BETWEEN CHANGES IN THE SPEED AT FULL LOAD AND THE EXHAUST TEMPERATURE

by running three series of tests at one-half load, at 1000 r.p.m. Two series were run with manifold *A* and a third series with manifold *B*. The tests on manifold *A* checked very well, the results being shown in Fig. 7.

In determining the effect of changing the speed, tests were run at speeds varying from 300 to 2000 r.p.m. and at light, one-half and full load, using manifold *B*. Figs. 8 and 9 show results that are characteristic of these tests.

The speed tests also show the effect of changing the load, as is indicated by Fig. 10. The maximum difference in exhaust temperatures between no load and full load is 270 deg. fahr., which occurs at the lowest speed used in these tests, namely, 300 r.p.m. As the speed in-

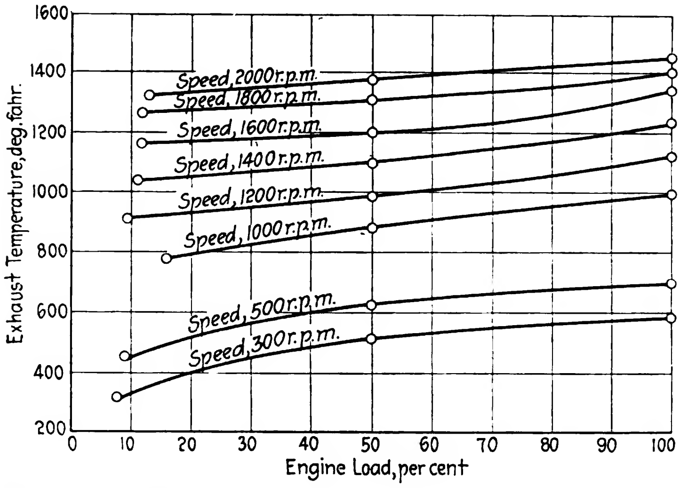


Fig. 10—Relation Between the Engine Load and the Exhaust Temperature at Different Speeds

creased, this difference decreased until, at 2000 r.p.m., it was only 110 deg. fahr.

The maximum exhaust temperature obtained at 2000 r.p.m. was 1460 deg. fahr., under full load, with a 31-deg. spark advance, a mixture temperature of 220 deg. fahr. and a mixture ratio of 0.08 lb. of gasoline per lb. of dry air. A special test was made at 300 r.p.m. with all of the conditions adjusted to produce the lowest possible temperature. It was possible to get down to 300 deg. fahr. under these conditions. It is obvious that the main factor in determining the exhaust temperatures is the speed at which the engine is running.

Discussion of Results

The tests show that the temperature of the exhaust gases from an engine vary through a wide range, according to the conditions under which the engine is running. They seldom get below 300 deg. fahr., even when the engine is idling at a very low speed, and do not often reach 1500 deg. fahr., even at full load and maximum speed. The lower end of this range is too low to be effective in vaporizing many of the fractions of petroleum that are offered to the public as fuel. There is little choice left to the designer or operator of an engine, however, as to what he can do to influence the exhaust temperatures. Nearly all of the factors influencing the engine performance must be adjusted to meet other more important requirements.

The speed and load of the engine are the main factors in determining the exhaust-gas temperatures, but they are governed usually by the service. To prevent getting below any specified exhaust-temperature, it will be best to operate the engine under conditions that will result in good performance and maximum power and efficiency, but to plan to stay above the special speeds and loads that are shown to be necessary in producing the desired temperature. The speed is more important than the load; so the principal requirement will be to stay above some specified speed.

An effort should be made to heat the fuel without heating the air in the manifold itself. There are two main reasons for this. The fuel can thus be vaporized at a very high temperature without the use of a great amount of heat, and this vaporization can be accomplished very rapidly. The dry fuel-vapor can then be mixed with cool air and drawn into the cylinder before it has time to condense and drop out of the mixture. The final mixture can thus be made usably dry at the lowest possible temperature. When the air is allowed to come in contact with the hot-spot, it becomes unnecessarily heated itself and tends to keep the metal in the hot-spot at too low a temperature to be most effective in vaporizing the fuel.

After completing this work, we feel that the greatest cause of the poor carburetion of our present engine-fuel is due to improper manifold design and that a great opportunity for progress lies in the improvement of the manifolding of engines. The advance will be made through learning how to use the heat in the exhaust gases and in introducing this heat into the intake charge in the proper amount and in the best way.

An important element in this problem, but one that lies outside of the scope of this paper, is the thermostatic control of carbureter temperatures. There is enough heat in the exhaust gases and the temperatures are high enough so that properly designed manifolds, together with thermostatically controlled carbureter temperatures, should make possible the satisfactory carburetion of fuels considerably heavier than our present "power" gasoline, without seriously limiting the power, efficiency or flexibility of passenger cars or resulting in any of the difficulties that are now due to poor manifolding systems. By a small increase in the minimum engine speed, still heavier fuels can be used. A careful study of how to use the exhaust heat best should therefore prove a great benefit to the whole motoring public, and a real step in the direction of progress. The manufacturers of the cars that are already built should take this fact seriously and provide not only for their future models but also produce improved manifolds that can be installed on their older cars, thus improving the quality of their service and prolonging their years of usefulness. It is our hope that the information we have assembled will prove of assistance to those in the industry who are striving to accomplish these results that are greatly to be desired.

THE MIDDLE WEST

FROM an agricultural standpoint the Middle West produces an abundance far beyond its own consuming power. With but little more than 50 per cent of the population of the United States and not more than 5 per cent of the world's population, this region produces approximately 20 per cent of all of the wheat grown throughout the entire world and 60 per cent of the world's corn crop.

In addition to producing these two essential food products, this portion of the United States is an important source for basic materials and a great manufacturing center. Here is produced over 30 per cent of the world's supply of bituminous coal, 37.6 per cent of the world's iron and steel, 42.0 per cent of the world's cotton, and 45.0 per cent of the world's oil. So far as transportation facilities are concerned, this region stands pre-eminent.

At least 44 per cent of the total manufactures of the United States are produced in this region. This, however, is but a fraction of its potential producing ability.

In 1920, the United States exported $4,163,354,637 of partly or wholly manufactured products. This represented about 50 per cent of the Country's total exports of domestic products. The Middle West contributed 44 per cent of this total, or $1,842,284,426.—W. F. Gephart in *The Economic World.*

The Relation of the Tractor to the Farm Implement

By G. DOUGLAS JONES[1]

MINNEAPOLIS TRACTOR MEETING PAPER

STATING that the trend of tractor development must be toward the small tractor that is capable of handling all of the power work on a farm, the author quotes farm and crop-acreage statistics and outlines diversified farming requirements, inclusive of row-crop cultivation.

Tractor requirements are stated to be for a sturdy compact design to meet the demands of the diversified farm, which include plowing, seeding, cultivating, hauling and belt-power usage, and these requirements are commented upon in general terms. Consideration is given to farm implements in connection with tractor operation, and the placing of cultivating implements ahead of the tractor is advocated.

FARM tractors have been in general use for more than a decade, but the industry finds itself still in the development stage. Its future will depend largely upon the ability of the tractor manufacturer to satisfy the farmer by providing both a power unit and suitable farm implements to accompany it that will accomplish his farm work without requiring any radical change in working methods. Therefore, the trend of development must be toward the small tractor that is capable of handling all of the power work on a farm, because the volume of sales must come from the smaller farms, which are in the majority by 4 to 1. These farms comprise an area of from 50 to 200 acres. The number of farms of this size in the United States is in excess of 4,000,000, while farms of greater acreage number slightly in excess of 1,000,000. The tendency of to-day is to reduce the acreage of the larger farms.

The average size of farm in the corn belt is approximately 100 acres. The same is true in the South. Even in Texas the records show the average to be approximately 125 acres. In the East farms average 100 acres. Thus the large acreage practically is confined to the inland empire. A simple method of illustrating farm volume is by the use of a pyramid. Let a section near the apex represent the large individual acreage with small tractor volume; let a section near the middle represent all individual acreage above 200 and below 1000 acres; and let the base section represent the farms of less than 200 acres. This base section represents the diversified crop area.

DIVERSIFIED-FARMING REQUIREMENTS

A farmer raising diversified crops must, of necessity, own and use a great many types of implement to carry on his farming successfully. A typical list of this farmer's implement requirements includes a plow, a disc harrow, a springtooth harrow, a drag harrow, a corn planter, a corn cultivator, a corn harvester, a wagon, a mower, and, in the majority of instances, a grain binder. In addition, the farmer has belt-driven units, which range from a circular saw to a threshing machine. A large investment is represented by these implements that are necessary to carry on his work successfully. All of them have been horse-drawn heretofore. They must be adapted to the tractor or the tractor must be adapted to them, before the farmer can get complete power-farming service.

The unusually high prices paid for farm products in 1919 and early in 1920 led the farmer to buy tractors indiscriminately. When prices again became normal many of these farmers found that their power equipment could not produce the crops at a profit on the basis of the new and lower market prices. This situation makes it doubly necessary that the tractor industry produce both tractors and implements that will compete effectually with the cost of raising farm crops by animal power. The problem before us is to meet this diversified farmer's requirements as completely as possible without interfering too severely with his present working methods. In considering the crops raised by him, the paramount obstacle has been his inability to handle intertillage work; that is, to cultivate his row crops.

ROW-CROP CULTIVATION

Although corn is grown on more than 102,075,000 acres in the United States, other row crops that must be considered include potatoes, with an average acreage of more than 4,000,000; cotton, covering an acreage in excess of 35,000,000; beans, which exceed 1,000,000 acres; peanuts, in excess of 1,000,000 acres and steadily increasing; and sugar beets, which average 1,000,000 acres and show a rapidly increasing acreage. There are many more important row-crops that cover smaller acreages, such as tobacco and truck crops, inclusive of cabbage, onions and tomatoes. They cover an acreage in excess of 2,000,000. Thus, we have approximately 146,075,000 acres of row crops in the United States, and practically all of this acreage is located on the smaller or diversified farms, where crop rotation plays an important part.

TRACTOR REQUIREMENTS

A tractor must be of sturdy and compact design to meet the demands of the diversified farm; yet it must be so simple that it can be operated easily after the briefest period of instruction. The accessibility of its working parts is just as important so that repairs can be made with minimum of delay and without the necessity of summoning an expert mechanic. Lubrication and greasing should be confined to no more than two points, so that the day's work in the field need not be cut short by tedious delays to attend to this rather vexing but all-important duty. This type of tractor, which appeals because of its cheapness of maintenance and simplicity of operation, must be adaptable to the farmer's manifold needs and to the implements that he already possesses. It is essential that he be not overburdened with the cost of purchasing new implements to effect this much-desired result.

Of the many tasks that fall to the diversified farmer, plowing is foremost of all. He must be able to plow

[1] M.S.A.E.—Agricultural engineer, Cleveland Tractor Co., Cleveland.

from 6 to 10 acres in a 10-hr. day with a two-bottom gangplow of the disc or the moldboard type. He must be able to travel at such speed as to pulverize for seed bedding the particular type of soil that predominates on his farm, eliminating the work of harrowing so far as possible. This requires a variety of speeds, for sandy soil demands far different treatment than clay or loam.

The new type of tractor must be able to exert adequate drawbar pull and at the same time be light enough to drag the harrow over the tilled field without packing the soil too firmly and retarding the germination of the budding seed. To accomplish this, the tractor must be able to pull a double-disc harrow, a spring-tooth harrow and a drag harrow, of such size and at such a rate of speed as to complete from 20 to 30 acres in a 10-hr. day. Tractor lightness is necessary also to permit the seeding machine to be hauled over the ground and yet leave the seed-bed in such a state of tilth that rapid germination of the seed will follow without the ill effects due to tramping or mashing the soil.

The tractor must be able to handle the long list of haulage jobs that are necessary on these farms throughout the year. It is evident how numerous these are, and what a variety of demands they entail. Cultivation of the soil is just as important as plowing in connection with the successful growth of row crops. In the past this work has been done by animal power or by special units primarily designed for cultivating. It is not necessary to have a specially designed powerplant unit that is used only during 6 to 8 weeks throughout the year, because all the essentials of this unit can be incorporated into the ideal tractor so that it can be used as expeditiously for cultivating as for any other farm work. Thorough cultivation is necessary; not a system of cultivation that covers the ground in the quickest manner possible, but a system that will bring about far better results than ever have been accomplished by handpower or animal power in the past. The problem is not a difficult one. It can be solved by tractor methods simply and easily if thought and effort are devoted to it. The ideal tractor must, of necessity, handle the numerous belt-power jobs on the farm, such as furnishing power for the feed mill, the wood saw, the corn shredder, the ensilage cutter, odd demands, the small cream-separator and the threshing machine. This problem of belt work has been and is being handled very satisfactorily by all tractors built today.

The requirements for a simple tractor for the diversified farmer demand a small compact sturdy machine of sufficient flexibility and ease of manipulation to handle all of the numerous tasks better, more cheaply and expeditiously than they have been handled in the past. Radical changes are needed. We still are holding to the cumbersome design of pioneer tractor that broke the virgin sod; one that caused endless delay through innumerable troubles and was designed primarily as a plowing unit. We must evolve a small design to meet the requirements of the farmer of today. This must be borne in mind constantly so that present-day implements will be available for use with the tractor. While making it rangy, the design must be kept simple, so that the tractor can be widened or narrowed and raised or lowered to give clearance, without the addition of complicated parts that require time and expense in the making of alterations.

Implement Requirements

Unobstructed vision for the operator is a prime requisite in the successful manipulation of cultivating implements. This can be accomplished most feasibly by placing the implements before the tractor, the driver being enabled thereby not only to manipulate the machine but to watch the progress of the work and note any emergency that arises. The working force can be cut in half in this manner. When the implement is drawn behind the tractor, a helper is necessary to manipulate it.

ORGANIZATION BY FARMERS

OUR Nation was established by one-man enterprise; the one-man farm whose products fed and clothed the family, the one-man store, the one-man blacksmith shop, the one-man stage coach, the one-man mail service. What distinguishes the Nation today is the fruit of associated, or organized, effort. Transportation, communication, manufacture, merchandising, are all conducted by great groups, often thousands of individuals, each with its leadership of superior ability, a leadership which has been earned by the survival of the fittest in years of competition.

Because every farm is a home, it is not likely to become factory organized; but agriculture, like other industries, has come to a time when all its problems cannot be solved by the farmer acting as an individual. Farmers must associate in groups. They must acquire the assistance and benefits of associated effort under skilled leadership. Successful leadership is the result of accumulated experience. The permanence and effectiveness of associated groups in agricultural efforts depends upon the development of successful leaders, able to read all factors aright, to think rightly and to decide rightly, to the end that all groups may prosper better because of the proper kind of leadership and the associated effort of many individuals acting in harmony.—President Van Norman of World's Dairy Congress Association.

THE BASIC INDUSTRY

WE frequently think of the iron and steel industry or some other industry with which we are most familiar as being the greatest and most important of the industries of the country upon which the prosperity of business mainly depends. But after all, the present business depression has shown that the country's prosperity depends largely on the buying power of the farmer. Nearly one-third of the people of the United States, or more than 30,000,000, live on farms. Nearly 20,000,000 live in communities having a population of less than 2500 and depend for their well-being mainly upon the prosperity of the farmer. In other words, nearly one-half of the population of the United States is directly dependent upon the farms for its income and its purchasing power. When this large part of the population begins to curtail its purchases to a minimum, as has been the case since the fall in the prices of farm products, every industry in the country suffers. In 1919 the value of the farm property in the United States was estimated at more than $50,000,000,000 or more than the combined capital of all the manufacturing establishments, railroads, mines and quarries in the country. The value of the output of the farms at prewar prices is estimated at $8,000,000,000.—*Machinery*.

Commercial-Body Supply and Service

By C. M. MANLY[1] AND C. B. VEAL[1]

CHICAGO SERVICE MEETING PAPER *Illustrated with* PHOTOGRAPHS

SPECIFYING the four general plans that have been followed by chassis builders in securing body equipment as being the building of bodies in their own shops; on contract by the body maker to plans and specifications of the chassis builder; by a local body maker to the order of the dealer or the owner; and the assembling from stock of standard sectional units recommended by the dealer or selected by the owner, the authors discuss each of these plans in detail.

With regard to the plan of using standardized sectional bodies, the different sizes of chassis used for commercial purposes are separated into four specified groups and the production of a complete standard line including a number of styles of body for each chassis is commented upon and illustrated, inclusive of detailed considerations of the all-metal body. The advantages to the dealer and to the user of the factors that are advocated in body building are enumerated, and the standardization of commercial cars and trucks is considered briefly.

SERVICE, in its broadest sense, must cover every phase of the marketing and operation of commercial motor vehicles and trucks. Whatever success is attained in the industry must be based fundamentally on *service*. Service to the dealer, good or bad, begins directly when the chassis is assembled, and continues through him, or directly to the consumer, throughout the usable life of the vehicle. The best interests of the dealer demand a service that results in the largest volume of sales, quickly made, with the minimum capital investment, and at the same time insures that greatest of all selling assets, *satisfied customers*.

The commercial car and truck chassis builder turns out, for the most part, a product that can be rendered useful only by the application of a body. Therefore, he should be vitally interested in having the final user of his vehicle obtain a body of good quality, properly mounted and adapted to the chassis and the work to be done. He is likewise concerned with everything that helps his dealers. The consumer, in this case the truck owner and operator, deserves to receive promptly, with a newly purchased chassis, a body suited to his needs with the assurance that it is durable and can be repaired with a minimum of delay and lost time for the vehicle.

The whole fabric of body service must be woven around the idea that a commercial motor vehicle has rendered its maximum of profit and usefulness only when the paying operation begins as soon as possible after it is assembled and continues steadily at a maximum per diem for the longest time with minimum losses through lay-ups for repairs and renewals. Any attempt to analyze the question of body service, therefore, must bring into consideration all phases of body design, production and distribution, as related to the chassis manufacturer, the dealer and the owner, as well as the body manufacturer, or builder.

Four distinct general plans have been followed by chassis builders in securing body equipment:

(1) Building in their own shop
(2) Building on contract by body maker to plans and specifications of chassis builder
(3) Building by local body maker to order of dealer or owner
(4) Assembling from stock standard sectional units recommended by dealer or selected by owner

All four are available, to a greater or less extent, at present and to determine the effect of each upon the ultimate question of service we will examine each plan as related to the interests of the chassis builder, the dealer and the owner.

CHASSIS BUILDER CONSTRUCTING BODIES

The chassis producer who attempts to enter the body-building all-metal bodies is contemplated. Even then the chassis with bodies, will find it necessary to make large investments in plant and equipment, as well as provide an entirely separate organization for their design and manufacture, since body-building is essentially a wood-working industry, as contrasted with the metal-working operations of chassis construction, unless the questionable procedure, treated more specifically later, of building all-matel bodies is contemplated. Even then the type of metal work involved is entirely different from that of chassis construction, and requires radically dissimilar shop and tool equipment and personnel. Many of the large sheet-metal workers have been kept out of the body business because sufficient quantities of bodies of uniform type and dimensions cannot be sold to make the tooling and other quantity-production worthwhile. The fact that some of these companies turned out truck bodies efficiently and at a low price for the Government in war time but have since found it unprofitable to produce for the trade under present conditions of standardization, or, rather, lack of standardization, should make clear to the chassis builder the inadvisability of going into the construction of metal bodies where the outlet for these bodies must necessarily be limited by the sales of their own chassis.

If the chassis builder plans anything like national distribution of his product, he must offer a line of bodies sufficient to meet the widely varying demand in different sections of the Country. To satisfy the requirements of Northern winters the driver must be protected from the cold with a complete enclosed job, while in California and the Southwest, in fact, all through the South, there is no market for such body types. In addition to these climatic considerations, every section of the Country insists upon certain features peculiar to itself, either because of more or less clearly defined limitations of the prevailing business in which the body is employed, or through unnecessary but obstinate adherence to established local custom.

Even if local distribution only is attempted, a considerable variety in types must be offered, for not only must "the butcher, the baker and the candlestick maker" be provided for, but the grocer, the department store, the

[1] M.S.A.E.—Consulting engineer, New York City.

manufacturer, the farmer, and, in fact, every conceivable business and trade, comes in for special attention in developing any adequate line of bodies.

A large proportion of the city demand will be for panel bodies, if for no better reason, because the large, plain panels of the sides have a real value for advertising purposes. In sparsely settled districts advertising space is of less value and consequently the small town and country merchant and tradesman will purchase only an express-type body, with or without top. The farmer generally has little use for the commercial body type that is most popular in the cities, and demands an entirely different design, depending in detail upon the particular branch of agriculture in which he is engaged. In the wheat belt his body must be grain-tight and preferably fitted with a special grain endgate and other features peculiarly suited to his needs. If he is raising cattle or hogs, he will probably want a stock body, and if this body can be equipped with a stock-loading chute, its sale will be made easier. While the general all-around farmer will prefer some form of universal, convertible platform-type of body, the dairy farmer will demand something different, the orchardist something else, and so on; each prospective purchaser will insist upon some type as being suited to his need. No scheme of body service will be satisfactory to these various consumers, or promote the best interests of the industry, that does not take seriously into account all the conditions leading up to their individual demands.

There are many groups of merchants that require more highly specialized bodies, such as ice-cream manufacturers, furniture dealers, florists and undertakers. Then there is a large class of users of dump-bodies or other bodies with special loading or unloading devices, including contractors and dealers in coal, lumber, sand, gravel, brick, cement and other builders' supplies.

The larger department-stores are representative of an extensive class of buyers who have created an unmistakable advertising value through years of use of bodies of distinctive, uniform design, painting and attractive appearance. For purely economic reasons, such users can ill afford to purchase bodies of varying type, even though the saving in first cost may be considerable.

Frequently peculiarities, not always evident to the outsider, in the transportation problems of a particular company fully justify the employment of highly specialized bodies, through savings actually effected thereby. In contrast with these cases, it is true that there is a large class of users, who, so far as efficient handling of their goods is concerned, could use a common type of body but, to gratify their personal preferences or pride or idiosyncrasies, insist upon exceptional construction and are willing to pay a higher price to obtain a body changed or built to suit them.

In the final analysis the chassis builder can find no better reason for entering the body-building field than that of increasing the sale of his chassis. A serious consideration of the widely varied types of body required to meet the demands of his market cannot but convince him that the investment and expense involved will be out of all proportion to the increased profit on his product if he attempts to cater to all prospective customers. On the other hand, limitation of the body types offered with his chassis to a very few standardized jobs, combined with insistence on selling the chassis and mounted body as a unit, is certain to result not only in small body sales but in reduced sales of chassis, since a large proportion of buyers will not take kindly to having a so-called standardized body forced upon them regardless of its suitability for their service. Under such circumstances the loss will be greater than any possible gain, since the customer will buy the chassis that gives him a free hand in obtaining the body best suited to his needs.

Commercial motor-vehicle bodies are too bulky to be shipped long distances economically by rail and, excepting the limited number of vehicles that can be driven away from the factory, the mounting of bodies at the builder's plant need not be considered as having any great possibilities.

One of the great obstacles in the way of chassis and body standardizaton has been the bulkiness of bodies in railroad freight transportation, the possibility of damage in shipment and the expense of crating. The prohibitive expense of shipping complete bodies "set-up" can be somewhat reduced by shipping them to dealers "knocked-down," thus increasing the number of bodies which may be placed in a 40-ft. freight-car from 6 to 16, and throwing the burden of assembly and mounting on the dealer.

In any case the dealer's capital requirements will be increased by having bodies added to the inventory that he must carry. If the line of bodies he has to offer is sufficient to meet the demand, the expense of storage space becomes no small item, while a limited line cannot meet competition and results in loss of sales through inability to assure proper body service to prospective chassis purchasers. It is generally accepted that the dealer in commercial cars and trucks can succeed only by selling transportation rather than simply vehicles and he cannot claim to sell transportation unless he is prepared to recommend the body types best adapted to the purchaser's needs. The whole process becomes still more expensive for the dealer if he must furnish the facilities and labor for assembling and mounting bodies.

If the chassis builder takes a compromise course and offers a medium number of well-selected types, of which the dealer carries a small stock continually, the most promising purchaser is likely to be disgruntled because the body service offered with the chassis is not all that he expects, or can obtain elsewhere, so far as variety is concerned. Even if he does not go elsewhere to buy at first, the dealer is certain to find it burdensome to carry parts and be prepared to make repairs on the limited number of each type going out on sales of complete units. As anything less than a maximum of service in repairing and remodeling bodies will prove unsatisfactory eventually to the user, the effort expended in trying to build up a permanent business of selling the chassis and the body as a unit is, with few exceptions, certain to be entirely out of proportion to the results attained.

Bodies Built According to Specification

The second plan, while it necessitates the chassis builder carrying a body-designing and engineering department, relieves him of the greater investment in shop and tool equipment and body fabricating organization. The body builder, through his ability to furnish other designs of his own for the trade and to take on contracts to supply various chassis producers, is in a much better position than the latter to acquire an adequate volume of body business for efficient and economical production. Here the advantage to all concerned, as compared with the first plan, ceases, however, since the distribution troubles remain the same, with the possible addition of an initial freight shipment of bodies from the body builder to the chassis plant, and the complications arising in repair service with the attendant embarrassment to the ultimate user through the interdependence of the chassis producer and the body builder in all matters of

responsibility affecting the guarantee, proper functioning and durability of the body. Of the four methods applicable to the supply of bodies for commercial vehicles and trucks having national distribution under existing conditions, undoubtedly this plan has the least to recommend it.

Custom-Built Bodies

The third plan, historically, has been the accepted method of most motor-vehicle builders upon first entering the commercial-car field, and is still the plan generally followed by the majority of truck companies. This practice came into effect not through the application of any special economic theory but rather through the natural working-out of conditions as they were and still are to a lamentable degree, especially in connection with heavy-duty trucks.

Comparatively few automobiles were used for commercial purposes until within the last ten years, and even as late as 1913 the bodies necessary for these few commercial chassis were built principally by small wagon-shops for the owner or furnished to him by the chassis builder. Where the body problem is put up to the dealer and he endeavors to answer it through the medium of the custom builder, he may expect bodies only slightly developed from those for horse-drawn wagons, in the production of which custom builders have, for the most part, obtained their experience. The result is a body of much greater weight than is necessary from an engineering standpoint, and built, rather than designed, without regard for the principles involved. Progress in the art of custom body-building for commercial transportation has been almost negligible, all alike having followed horse tradition. Nor is progress to be expected from the local body-builder, hampered as he is by tradition and lack of technical training; he cannot advance even if he desires to advance.

With the exception of dealers in vehicles of exceptionally high quality, the dealer is forced by competition to obtain a fairly good body at a medium price. The methods and equipment of the local builder are usually very crude. He generally has little or no modern woodworking machinery and must depend upon tedious handwork for all or most of the fitted parts. Through hurry, carelessness, or improper supervision, poor workmanship results. Such bodies, loosely fitted together, soon become wobbly, decay sets in prematurely from moisture getting into the joints and the life of the body is wofully reduced.

Fig. 2—Interior of Partially Assembled Panel Body and Rear Door

The dealer who expects to get from the local builder just what he specifies at a low or even a medium price is certain to experience disappointment. But not all custom bodies are poorly built; many of them show exceptional workmanship and materials. The difficulty with

Fig. 1—Standardized Sectional Panel Body Showing the Principal Sectional Units in Approximately Their Proper Relative Positions

such bodies is that the price is disproportionately high, and even the best of them, constructed with the most conscientious care, are usually deficient in some particular. The making of the body is based on the more or less restricted experience of the builder who, as a practical man, following custom, has exaggerated the care and expense above the true requirements in certain details. Under the critical inspection of a competent engineer, wasted effort will be evident in the construction of virtually all good custom-bodies. In his anxiety to turn out a durable product and always "throw any errors on the safe side," the small, scrupulous builder is inclined to use timber a little larger than necessary here and there and place heavy and elaborate iron forgings where they can do no good. All of this adds to the price and, as increased non-pay load, permanently reduces the efficiency of the vehicle by just that much as a transportation unit.

The dealer is quick to realize the loss he sustains through delayed deliveries of the chassis while he waits for a body to be built. Both dealer and customer are aggravated and suffer a substantial loss during this period of waiting, which may run into weeks after the truck is sold. The tying-up of the dealer's money in chassis inventories presents a retardation in the process of merchandising that cannot be ignored by the chassis builder. He should be just as much interested as the dealer in having his chassis promptly placed in active service, for idle equipment represents an investment earning no interest, a definite economic waste that, like time itself, cannot be recovered.

This plan of body handling leaves the dealer almost powerless in rendering service to the buyer in matters of repair, all of which are likely to prove relatively expensive in both time and direct cost; a condition that is rendered more exasperating by enforced total loss in earning capacity of the vehicle while it is laid up for repairs, which commonly takes considerably more time than the proportionate value of the parts affected, because the custom body-builder habitually gives little or no attention to the incorporation in his product of features that will facilitate rapid and economical repair.

Standardized Sectional Bodies

The successful operation of the *fourth* plan has been made possible only comparatively recently owing to a lack of sufficient demand and the continuous evolutionary changes in body requirements as the business developed. Through the adoption of this plan the chassis builder and his dealer derive a great many benefits. Not the least of these for the former is complete relief from the undertaking of body-building. While eliminating the capital investment involved in the *first* plan, he simultaneously removes from his dealers the burden of body inventories common to the *first* and *second* plans. Moreover, he is assured that his chassis will not be abused by being made to carry a poorly proportioned or ill-fitting body of excessive weight or capacity. The dealer is further helped by overcoming the slowing-up of merchandising while waiting for each body to be built individually under the *third* plan.

To assist in getting a clear understanding of the development and possibilities of this whole scheme, a distinction will be made between the different sizes of chassis used for commercial purposes, dividing them into the following classes:

(1) Commercial chassis, requiring a "commercial body," comprising all light popular chassis, whether designed primarily for passenger or commercial purposes, with a rating of less than 1 ton

(2) Truck chassis, rated at 1 to 1½ tons, requiring a truck body

(3) Truck chassis, rated at 2 to 2½ tons, requiring a truck body

(4) Truck chassis, rated at 3 to 5 tons, requiring a truck body

The plan involves the production of a complete standard line including a number of styles of body for each chassis.

The large volume of trade available in a single design of chassis early in the commercial-car business made possible the successful beginning of standardization in stock bodies for the first class of vehicle and, as bodies for both the first and the second classes have now been standardized thoroughly, they can be treated, not as a theory, but as a matter of practical accomplishment, and the results regarded as an indication of what can be accomplished by the standardization of heavy-duty trucks.

The prospect of a large market for these lighter bodies has permitted the treatment of body design, production and maintenance as engineering problems to an extent never before realized in the body field. The needs of every large class of users have been analyzed thoroughly and standard types developed, each with features that fit it to the actual requirements. There is occasionally some exceptional service that cannot be satisfied by any possible standard, but the vast majority can find what they want in the standard types. The demand for infinite variety is founded on custom and prejudice rather than practical experience or analysis, and a trial usually convinces the buyer that the design of the standard body for his use is based on a more comprehensive and accurate study of his requirements than he could possibly make for himself.

By building the bodies in sections and standardizing these sections, it has been found possible to use certain sections for very many different types of these bodies. In some respects, the scheme parallels, although in a very different field and with much greater economic possibilities, the flexibility and utility of the sectional bookcase. Standardization has been carried to such an extent that the reduction in the total number of component parts has diminished noticeably the body-builder's investment in raw materials, work in process and finished goods.

Many major parts of bodies and cabs are interchangeable on various types of body. Starting with one platform or base, a choice can be made from several side-panels, rear sections and tops, thus making it possible to assemble any one of, literally, a dozen body styles on this one design of base. Likewise, doors and windshields used on cabs or vestibules can be assembled interchangeably with a variety of other body units. In fact, windshield, vestibule doors, vestibule side-windows, rear doors, toe-boards, cushion and lazy-back are worked out readily, each in a single-unit design common to all bodies of whatever model where any one of these items is required. A single endgate can be used to equip many different models.

Fig. 1 shows several of the principal sectional units of a panel body, and illustrates how these units can be built easily into a substantial assembly. Fig. 2 shows the interior of the same body partially assembled with the rear door in place. Interior and exterior views of a vestibule door common to all closed-vestibule bodies is shown in Fig. 3, while Fig. 4 clearly indicates a standard seat-cushion and lazy-back construction.

Fig. 5 illustrates the six consecutive operations in

FIG. 3—INTERIOR SIDE OF THE VESTIBULE DOOR SECTION AT THE LEFT AND AT THE RIGHT THE EXTERIOR

the assembly of a six-post express-body with a vestibule compartment for the driver, including doors that can be held open by a special fastener when it is desired to use the body with an open front. An inspection of these illustrations, taken in order, demonstrates how, beginning with the platform, the side-panels, the toe-board brackets, the seat, the top, the endgate, the toe-boards, the windshield and the vestibule doors are added as separate unit-sections to make up the complete body. An examination of these views also serves to make clear how comparatively easy it is to replace any section in overhauling or repair.

Standardization on a few stock sizes of lumber has made possible its purchase under carefully prepared specifications that insure a quality best suited to the purpose at reduced prices. In the case of the heavier frame and platform members it permits the direct shipment of properly conditioned and seasoned fully machined parts from the lumber-mill to the body assembly plants. This reduces the weight to a low minimum before shipment, since it is fully dried instead of green and all waste in the machine-finishing of the parts occurs at the lumber mill before shipment. The total cost of freightage is still further reduced by replacing the double haul from the lumber-mill to the fabricating plant for machining and then on to the assembling plant, by a single shipment from the mill direct to the assembling plant. By adopting efficient quantity-production methods in the manufacture and subassembly of parts, substituting machine for hand labor and manufacturing and fabricating the parts and units under steel jigs, the quality has become more uniform and better at a reduced cost, which has been lowered still further by simplifying operations, decreasing the number of operations and making possible the employment of a less skilled class of workmen.

In no phase of the body-builder's activities is the gain of the standardized sectional body over the earlier forms of construction more evident than in freight shipment. Whereas only six bodies, completely set-up, can be shipped in a 40-ft. freight-car, this number can be increased to a maximum of 16 by having them "knocked down". After the bodies are completely built and set-up by body-makers and have been put through the painting and trimming departments they are sent to the shipping department where the tops and sides are disconnected and then crated for loading in the car. Sectional units for 40 bodies can be packed in the same car, with a much lower rate classification, effecting a striking saving in freight-cost and in the labor of assembling, disassembling and crating.

To pass a maximum of these economies on to the dealer and insure continuous service to the user, the advantages of this plan are still further extended by establishing factory assembling-branches in all large distributing centers, carrying complete stocks of bodies and parts and well equipped for mounting, painting, lettering and repairing. The body sections, as received from the fabricating plants by those branches, occupy a minimum of storage space and need be assembled only to care for sales demands. At first many were skeptical concerning the possibility of turning out body sections with sufficient accuracy to make all parts interchangeable and permit assembly in the fabricating plant, at assembling branches or by dealers themselves. Of course, it had been fully established that this could be done in the case of machines composed of all-metal parts, but it had to be demonstrated that this is not rendered impracticable in a combination of wood and steel by the expansion and contraction of wood caused by variations in moisture and temperature. While it is true that extraordinary care must be taken in the selection and conditioning of the lumber and finished

FIG. 4—CONSTRUCTION OF SEAT AND CUSHION UNITS

wood-parts, all this attention, in quantity operations, results in little additional expense, and this is more than offset by improved quality in the product as compared with bodies built under less exacting conditions.

Metal Bodies

While the all-metal body may, apparently, offer attractive features from the standpoint of quantity production, as affecting the purchase price, it must not be forgotten that maintenance cost and useful life, or depreciation charge, are equally and frequently more important in determining the maximum utility of any transportation unit. The railroad freight-car probably offers as close a parallel to motor-truck bodies in the requirements to be met as can be found in any long-established business. The experience of the railroads with all-metal freight-cars certainly does not justify the conclusion that metal truck-bodies will find very general acceptance in the near future, although the all-metal body will, undoubtedly, continue to meet the demands of certain restricted classes of motor-truck haulage. Some of the railroads recently have converted all their steel coal-cars into the so-called "composite", wood and metal, cars, substituting wood for the steel floor-plates, side-sheets and hopper-doors. Others unconditionally recommend the wood body on account of the corrosion of the steel.

The history in the railroad industry is, briefly, that for many years freight-cars were built altogether of wood, with only sufficient steel parts to tie it together. About 1890 a few firms started to build steel cars. The industry was stampeded and there was a rapid revolutionary movement to the steel car, and, as usual, the pendulum swung too far, forcing great loss upon all concerned before the industry could recognize the advantages of both lumber and steel properly combined and each used in its proper place. The result at the present time is the composite car, which the master car builders have found to possess advantages in all essential factors.

The first cost of the composite car is much less, quality considered, than that of the all-steel freight-car. The average cost of repairing composite cars is less than 40 per cent of that of steel cars in the same service, and the former can be repaired in one-half the time necessary to repair the latter. Furthermore, the composite car can be repaired fully with many materials locally available and without any special equipment, while the all-steel car can be repaired or rebuilt only in a manufacturing establishment equipped with special presses and machinery representing no inconsiderable investment. One of the factors seriously entering into the maintenance and depreciation charges is the fact that in case of a bad accident an all-steel car is frequently almost a complete loss, due to the practical impossibility of economical repair. Railroad operating officials have come to regard the steel car as an unwarranted transportation cost in view of the period of their actual worthwhile service being limited to 10 years; whereas the life of ordinary composite equipment under normal conditions is at least 20 years. Thus both the reproduction value and the actual depreciation of composite cars are less than these costs for all-steel cars.

The average composite car weighs approximately 1000 lb. less than corresponding steel cars. The wood sides do not bulge as the sides of steel cars bulge. The composite car is better for shippers in packing and loading, since greater protection is obtained for the contents of the car, and no precautions are necessary against rusted side-sheets, bulging ends, condensation from roofs or leaks of bulk lading through holes in corrugated sheets.

The all-metal underframe for freight cars, unquestionably, has been justified by experience. In motor vehicles its function is served, substantially, by the chassis frame. While metal members will, undoubtedly, prove of increasing importance in the framing and bracing of motor-vehicle bodies, and designers will do well to incorporate gradually more light metal parts, it is believed that the deficiency of metal in some of the properties, notably resilience, required in truck bodies will prohibit its general adoption to the exclusion of composite wood and metal body-frames. The excuse for metal end-panels does not exist in motor truck as in freight-car bodies.

The advantages of first cost demonstrated by the composite freight-car apply in the same manner, although possibly to a less degree, to motor-truck bodies. The item of maintenance and repair should result in an even greater advantage for the combined wood and metal body as compared with the all-metal body upon which only minor repairs can be made outside a specially equipped shop. Even when such a shop is available, major repairs cannot be made, without unwarranted difficulty and expense, if at all.

A vehicle operating on the streets and public roads is caught in a collision or otherwise damaged so much more frequently than a freight-car operating upon steel rails of a private right-of-way, that the occasion for repairs becomes greater, and, when necessary, a metal-braced and reinforced wood body can be repaired quickly and cheaply with material generally at hand, by an average workman. A steel body, on the other hand, whose parts are specially formed and held together by welding, riveting or some other permanent jointing, presents an expensive, if at all practical, repair job. The same properties that make for difficulty in repair work also restrict or entirely eliminate one element of service that is decidedly in favor of the composite body; namely, there are many little utility changes that the user may need to make to meet the requirements of his own business better. In the composite body, with lumber as the principal material, a saw will readily remove any portion and any handy carpenter with nails and screws can make any desired change easily.

The decrease in weight effected through the use of the composite body, as compared with the all-steel construction, is of even greater importance in the case of the motor car than of the railroad car. To a certain extent there is less likelihood of damage resulting to the load from the body itself where it is made of wood instead of steel.

Advantages to Dealer

The accumulated savings due to increased purchasing power, elimination of waste, economical production and distribution methods, and reduced labor, freight and storage charges, when passed on to the dealer, enable him to offer his customers the combined unit of chassis and body at a lower price than it can be secured by any other practical solution of the body problem. These combined benefits can be attained only by quantity output, assured through national distribution of a very complete line and accompanied by the ability to equip not only the chassis of one but those of several of the largest builders.

The lower price at which standardized production bodies can be sold benefits the dealer directly through increased sales. The dealer's volume of sales is further

extended by the development of large new fields for the sale of chassis, made possible by the creation of standardized body-types especially suited to these fields. In fact, the body builder has been, and still is, doing as much as, if not more than, the chassis builder in developing new fields for the use of commercial cars. The opening of new provinces of employment for the motor car by the creation of special bodies is well illustrated by the variously called park, country-club or suburban bodies. Thousands of light chassis with these bodies are now sold every year, and their sale is increasing very rapidly. Well-to-do people, with country estates or suburban homes, frequently use a light, popular-priced chassis with this body as a general utility car for taking passengers, baggage or freight to and from the railroad station, marketing, going to the golf club, or general knockabout purposes.

Not the least of the advantages to the dealer is that

Fig. 5—Successive Stages in the Assembling of the Standardized Sectional Body
The Upper Pair of Views Show the Body Platform Being Placed in Position for Assembly and the Side Section Being Mounted Respectively. In the Middle View at the Left the Toe-Board Brackets Are Being Attached and at the Right the Top Is Being Put On. The Tail Gate Is Being Placed in Position in the Lower Left Corner and Adding the Vestibule Doors and the Toe-Boards, Which Are the Last Steps, Are Shown in the Lower Right

of immediate delivery. In common with most purchasers, the commercial-car or truck prospect generally postpones the buying of a new vehicle as long as possible but, when finally he is persuaded to close a deal, he wants the car immediately. It may be that his old chassis has broken down suddenly, or that additional transportation must be provided for at once. In any case the buyer does not want to wait. Consequently, the dealer who can make immediate delivery of the chassis complete with body, ready for service, has a very tangible advantage, for the chassis without the body is of no use to the purchaser. To reap the full benefit of prompt delivery, the dealer must be able to offer a sufficiently wide line of types to meet all the usual demands. With the assistance of the body-builder's engineers the dealer is able to give the customer expert advice regarding the type of body best suited to his business. Furthermore, the body builder, through his branch assembly-plants, is prepared to give the buyer not only what he needs but what he may reasonably want in the way of special painting, lettering, accessories, numerous variations or additions, in rear and front enclosures, shelves, partitions, doors, etc., so long as the standard basic sections are employed without variation in the design and dimensions.

If the volume of his business is sufficient, the dealer can carry profitably on the floor of his own showroom various bodies, the "best-sellers", mounted on his chassis for demonstration purposes. But whether or not the chassis dealer exhibits sample bodies, the body builder's branch should maintain salesrooms and displays where the dealer can show his customer exactly the type of body he is to get. Incidentally, the branch organization becomes a very potent factor in assisting and making sales for the chassis dealer, who finds that often particularly difficult customers can be brought to the closing-point by taking them to the body builder's branch and showing them well-made and well-finished bodies and giving them the advantage of the body engineers' advice as to style and type. Thus, these branches not only carry the necessary complete line of bodies and parts to meet the needs of dealers and customers, but they render many helpful services to both in turning out the fully equipped unit.

Not only does the dealer benefit by increased chassis sales, but by handling the body sale he realizes an additional profit on the body itself in discounts in which he is protected by the reliable manufacturer. This profit, while attractive to the dealer, does not detract seriously from the economies effected by quantity production.

With this scheme of body supply the dealer not only avoids tieing up his capital in carrying a stock of bodies but, by quicker sales and more especially by immediate delivery and collection, he is able to reduce the time his money is lying idle in the chassis by from three to six weeks, or even more in many cases.

Advantages to User

That which helps the dealer benefits the chassis builder indirectly, and, to a great extent, the advantages that they enjoy are passed on to the owner and operator. Better bodies at more attractive prices and immediate delivery are the first of these benefits to appeal to the user. When he finds that without losing any of these he can obtain, generally, exactly what he wants and, if not, a body designed to satisfy his actual needs, he is not likely to look further in making his initial purchase of body equipment. It is after purchase, however, that he experiences the greatest advantage of this method; namely, prompt, effective and economical service and repair. If he has been a user of custom-built bodies, individually fitted together by hand by body-builders, he has learned that they are usually framed so that in case of damage it is almost as expensive to repair a body as to purchase a new one. Also, he has found that the small body-builder, after supplying the original body, makes no pretense of giving service on the body. Under these conditions the user not only has to pay the local small shop an excessive price for repairs but he must bear an even greater expense in that his whole investment in the chassis and the body is tied up and his business suffers heavily while his equipment is out of commission.

A standardized sectional body can be smashed by collision or other accident and, regardless of the extent of damage, within a very few hours any damaged piece, or entire sections, can be replaced, if necessary. The manufacture of interchangeable body-parts, reduced to a low minimum in variety, coupled with attention in design to facilitating replacement, offers about all that can be expected reasonably in the possibilities of quick, economical repair.

The extent to which these possibilities have been realized in actual practice is well illustrated by three typical cases. One of the large accident-insurance companies, in the settlement of a claim for damages to a 1-ton truck partially wrecked by a street-car in St. Louis, undertook recently to repair a standardized sectional body. Three quotations were obtained, two from local body-builders and one from the body builder's local branch. The builders each required 2 weeks to put the body into shape, and the quotations were $168 and $192, respectively, while the body builder's branch quoted $52, naturally got the job and actually completed the repair, putting in a new side and a new panel, in 2 hr. time. A Boston truck-gardener skidded across the Charles Street Bridge, smashing a side-panel and part of the top of the truck body. Having but the one truck, he needed it every day and could not afford to lay it up for repair. Fortunately for him, it was a standardized sectional body, and the builder's branch replaced the side panel and top and had the truck back on the street in 18 min. A dairy company operating a fleet in New York City, building its own bodies and maintaining repair and paint shops, purchased three sectional bodies because they had to have equipment at once. On the first day of operation one job had an accident, smashing a side-panel and the top against a pillar on the Third Avenue elevated railroad. Finding that it would require 2 weeks to make the repair in its own shop, the company appealed to the body builder's local branch, which turned the job out in the regular course of the day's work in less than 5 hr.

Similar examples of prompt and economical service could be added indefinitely, but these are typical and indicate what has been accomplished. The fact that all parts and body sections are built on thoroughly co-ordinated jigs, thus insuring easy assembling and the perfect fitting of all parts, makes possible such exceptional low cost and speed in handling repairs and replacement.

Standardization of Commercial Cars and Trucks

The largest builders of light chassis have modified their stripped chassis offered for commercial purposes to accommodate the mounting of existing models of

(*Concluded on page* 211)

Internal-Combustion Engine Fuels

By C. A. NORMAN[1]

MINNEAPOLIS SECTION PAPER

AFTER pointing out that although kerosene costs less than gasoline at the present time and is a cheaper fuel for the farmer to use, the author states that if the industry continues to construct tractors designed to use kerosene as fuel it will not be long before the cost of it is the same as that of gasoline. He argues that automotive engines should be designed to run on any liquid fuel and gives figures on the available supply of petroleum products and distillates in the world at the present time. The requirements laid down by the Government for gasoline are mentioned and it is stated that it is not possible for the oil industry to supply generally to the trade a gasoline meeting the recently adopted Government specifications which the author considers are very lenient. The possibilities of utilizing the cracking process to increase the gasoline supply are referred to but the author considers it economically sounder to develop automotive engines to run efficiently on uncracked fuel, pointing out what has been done abroad in developing the injection type of engine for airplanes, automobiles and tractors.

A table giving data on practically all of the liquid fuels that have been considered in the past five or six years is presented and the advantages and disadvantages of these are brought out, together with information on the available supply. Considerable attention is paid to the possibility of utilizing the various farm-product sources of alcohol and the conclusion is reached that such utilization is not practicable under the present prices that are being paid for various products. Mention is made of a process that is being employed in Switzerland for producing alcohol from coal. In conclusion the possibilities of utilizing oil shales as a source of fuel are emphasized.

I UNDERSTAND that you are interested in fuel substitutes, that you have tried to construct tractors to utilize kerosene as fuel and that you have had trouble with kerosene. If I ask why you have been designing tractors to run on kerosene, your probable answer will be that kerosene costs much less than gasoline and is a cheaper fuel for the farmer to use. This condition may not endure, however. It is as difficult to produce kerosene as it is to produce gasoline. If you continue to construct tractors to run on kerosene, in a short time kerosene will cost as much as gasoline.

The prices in Kansas City are a fair example of the price movement of kerosene within the past few years. In 1917 the market price there was 6.8 cents per gal., but that price had increased to 17.6 cents by June 30, 1920. In 1917 gasoline was 18.2 cents per gal. and by June 30, 1920, it had increased to 26.2 cents. The increase in the price of gasoline was 44 per cent and that of kerosene 160 per cent. Kerosene in 1917 cost only 37 per cent of what gasoline cost at Kansas City; in 1920 it cost 67 per cent of what gasoline cost. The production of kerosene has increased very little. In 1909 we produced 40,000,000 bbl. and in 1919 55,000,000 bbl., an increase of something like 37 per cent; at the same time gasoline production increased from 15,000,000 to 94,000,000 bbl., an increase of 600 per cent.

Our home use of kerosene reached its minimum in 1916; it was very small. From that time the home use has increased and the exports have decreased. There is a parallel between the great increase in price and the increase in home use. Tractors came into use after 1916 in tremendously increasing numbers and the growing use of kerosene in tractor operation had much to do with the rise in the price of kerosene. I am therefore justified in saying that the more tractors are adapted to run on kerosene, the higher the cost of kerosene will become. Before the development of anything new is begun, it is of extreme importance to consider carefully the fuel situation and the economic conditions that must be met; otherwise we might find that after years of effort we had produced something of no economic value whatever.

Regarding the present necessity, my opinion is that engines should be designed so that they will run on any liquid fuel; not only to run on gasoline or kerosene, but on a mixture of the two. I think that can be done. I will try to show what we have available in the world today in the way of petroleum products and distillates of petroleum, so that we may know the rational line to follow in tractor design to meet the fuel situation as it is.

AVAILABLE SUPPLY OF PETROLEUM

We have to-day, according to David White, about 7,000,000,000 bbl. of crude oil in the United States that can be extracted from the ground by present-day methods of production. Those methods are very inefficient. J. O. Lewis, of the Bureau of Mines, states that probably about 50 to 70 per cent of the crude oil is never extracted but remains in the ground. The experts in the Bureau of Mines have accomplished much toward improving the methods of extracting oil. The consumption of crude oil in the United States at present is over 400,000,000 bbl. per year. This means that our petroleum resources may be exhausted in something like 14 or 15 years. The question is, what will happen then?

We know that long before such a condition occurs production will commence to drop. Mr. White's estimate seems to be that the maximum production of crude oil for the United States will occur about the year 1925. Up to that time we will produce 450,000,000 bbl. of crude oil per year; after that the United States' production will go down. We actually consume in this country about 450,000,000 bbl. per year at present; so, from 1925 on, it will be a physical impossibility for this country to produce the crude oil it needs. Where is the remainder to come from. During the war we were looking for substitutes such as alcohol and benzol. We found we had tremendous shale-oil resources. We found also that there are very large petroleum resources outside of the United States. At the Petroleum Congress in November, 1920, in Washington, the predominant note was that we ought to be able to get into all oil fields beyond the boundaries of the United States, no matter where they are, on an equal footing with everyone else and derive our oil mainly from abroad.

In 1919 we imported 53,000,000 bbl. of oil from Mexico. We exported 60,000,000 bbl. of petroleum products. We could have eliminated the importation if we had kept all our petroleum products at home. However, at present we are importing from Mexico 60,000,000 to 70,000,000 bbl. and are actually depending upon the outside

[1] M.S.A.E.—Professor of machine design, Ohio State University, Columbus, Ohio.

world for our crude oil supply to the extent of perhaps 20,000,000 bbl. The question is, can we continue to do that? The best estimates that can be procured are made by Eugene Stebinger, of the United States Geological Survey, who is an expert on foreign oil fields. There is a small supply in Canada; in Mexico about 4,500,000,000 bbl.; in Northern South America, including Peru, 5,700,000,000 bbl.; and in Southern South America about 3,500,000,000 bbl. That includes about all the supplies of oil in this hemisphere. We find oil in quantities of, roughly, 5,500,000,000 bbl. available in Persia and Mesopotamia, 5,500,000,000 bbl. in Russia and 3,000,000,000 bbl. in the East Indies.

Can we get this oil if we want it? Here we are faced with a most startling situation. It appears that while we have been exhausting our natural resources at a terrific rate, Great Britain has put oil resources under her commercial and in some cases her political sway, all over the globe. She controls at present, directly and indirectly, 75 per cent of the world's future oil supply. The oil in Persia is controlled by an agreement with the Persian Government. The oil in Mesopotamia is controlled jointly by France and England. Holland shuts out all nationals except the Dutch from the exploitation of oil in Java. In other places British capital simply is in control. We must compete with Great Britain to obtain oil from the countries on this side of the globe.

If we do not want to be dependent upon foreign countries for our fuel supply, we must face the situation that within three or four years we cannot supply our present need of crude petroleum, and look for available substitutes that we can get within the boundaries of the United States. In seeking a substitute for petroleum we might perhaps not wish to substitute something akin to crude oil. We do not use the oil as crude oil; in most cases we use it in other forms. In 1919 this country consumed 88,000,000 bbl. of gasoline. The total amount of gasoline extracted from crude petroleum was slightly over 23 per cent; that is more gasoline, so-called, than is actually obtained in petroleum naturally. The specifications issued originally showed that gasoline was the portion that distilled over below 150 deg. cent.; that is, below 300 deg. fahr. We know nothing of such gasoline to-day. The Government now specifies three grades of gasoline; first, the finer grade of aviation gasoline that has an end-point of 329 deg. fahr.; second, the domestic grade of aviation gasoline that must distill over below 374 deg. fahr., and third, ordinary engine gasoline used for passenger cars and trucks, which must distill over below 437 deg. fahr., an increase over former Government specifications which called for 425 deg. fahr. The question arises whether those specifications are actually met at present. The Bureau of Mines conducted an investigation in seven of the largest States. It was found that there was a great quantity of gasoline in each of these States that did not meet the very lenient requirements, and further that the average gasoline for the country did not meet them and that the average gasoline in the United States had an end-point of 456 deg. fahr. At present it is not possible for the oil industry to supply generally to the trade a gasoline meeting the most lenient specifications that the Government considers it advisable to adopt. This means that we are faced with an emergency.

Boiling Points and Specific Gravity

I wish to comment upon our unfortunate habit of buying gasoline by its specific-gravity rating. What we want is a fuel that we can send through the carbureter and the inlet-manifold to be picked up readily by the air and go as a uniform mixture into the cylinders. This requires a certain volatility; that the fuel evaporate easily; that the boiling point have a certain maximum value and that the heat of evaporation be not beyond a certain maximum value. But it makes no difference what specific gravity the fuel has. Alcohol and benzol weigh considerably more per gal. than gasoline. Benzol distills over entirely at 176 deg. fahr. and alcohol at 172 deg. fahr. They are both very much more volatile than gasoline so far as the boiling point is concerned, and yet they are heavier. So, we must remember the boiling points and disregard the specific gravity. Selling gasoline by its specific-gravity rating may be of advantage to the oil companies. They may produce an oil having very heavy fractions that they mix with light fractions. This, however, may result in a fuel, part of which will not evaporate in the manifold at all, while part will be so volatile as to be inconvenient and dangerous. The Baumé scale will show it to be all right as regards specific gravity, but as a fuel it is all wrong. One-half of it is too light and the other half is too heavy to evaporate. We should eliminate the buying of fuel by its specific-gravity rating; we should buy it by its distillation test.

Cracking

It is a serious matter that the average gasoline of the United States does not meet what the Government considers a satisfactory specification for gasoline. The oil companies have been forced to adopt this deteriorated grade of gasoline on account of the automotive demand. We have come to the point where there is one automobile for ever 12 inhabitants of this Country. One can calculate readily the enormous demand thus constituted. It is a demand that cannot be supplied without straining our idea of what gasoline is and adopting new production methods. One method now being used is to compress and refrigerate natural gas. In that way we obtain so-called casing-head gasoline; present-day gasoline contains about 7 per cent of it. We can crack low-grade oil and produce gasoline. The Standard Oil Co. has done that for a long time, using the Burton process of cracking under pressure. The Bureau of Mines has worked out another method, the Rittman process, which also produces gasoline from raw fuel. The Burton process is a commercial success and present-day gasoline contains about 8 to 10 per cent of cracked gasoline. The Rittman process seems to be a success, judging from the published reports, but its use has not spread very fast. By those two processes it is possible to produce from heavy and from light distillates a large quantity of gasoline. Rittman claims that he can convert 80 per cent of the original oil into gasoline. This would mean that we would have twice as much gasoline as we use and need in this country at present, or for some time to come. Arthur D. Little, Inc., a chemical engineering firm in Boston, has issued a pamphlet which seems to indicate, as its opinion, a cracking limit of 60 or 70 per cent. From our present production of crude oil we could then produce by cracking something like 300,000,000 bbl. of gasoline, and that would supply our automotive needs for some time.

Injection-Type Automotive Engine

However, cracking involves labor and considerable material. If we can develop automotive engines to run efficiently on uncracked fuel, this would certainly be a sounder solution of the fuel problem than cracking. It is well known that we have stationary and marine engines

that utilize uncracked fuel. In Germany, the Junkers airplane engine also seems able to do this. It is an injection-type engine, operating on a somewhat modified Diesel principle. In France the Bellern and Bregeras engines, operating on a more modified injection principle, have been successful in automobile operation on kerosene. In England the Blackstone injection engine has been adapted to a tractor; and news has come of the Steinbecker injection engine being adapted to automobiles in Germany. So the injection-type automobile engine is already more than a dream. Very possibly we have not in this country at the present time an injection engine that could be turned over to an untrained farmhand to operate. But if one-tenth of the effort now spent on the carbureting engine were concentrated on the automotive injection engine, it is certainly not unreasonable to expect that we would have a practical automotive injection engine in a short time.

The great trouble is that the carbureter engine in automotive service is extremely inefficient. When running cars on the road we do not use more than 20 per cent of the maximum power of the engine. With such loads 150 per cent more fuel per horsepower-hour is required than at full load, while the Diesel or injection engine will run more economically at one-half than at full load, and at one-quarter load may require only 15 per cent more fuel per horsepower-hour than at full load. I think the present situation indicates that the latter type is the most desirable engine. With its aid we could save 50 per cent of our fuel. Instead of having our fuel resources exhausted in 15 years, they would not become exhausted in less than 30 years. This sort of thing is being done in Germany and it can be done here. We ought to worry about this more than about fuel substitutes. Commenting on the attempts that have been made to improve the performance of the carbureter engine, a trade paper[2] states that by introducing an extra inlet-valve on the engine, which is never throttled, the mileage on automobiles has been doubled. The paper by A. L. Nelson on the Fuel Problem in Relation to Engineering Viewpoint[3] contains other suggestions about how to obtain fuel economy. These papers should be read with great care and the suggestions contained therein followed.

[2] See *Automotive Industries*, Jan. 27, 1921, p. 185.
[3] See THE JOURNAL, February, 1921, p. 101.

SUBSTITUTE FUELS

Table 1 shows about all of the liquid fuels that have been considered during the last five or six years. It includes the fuels that were developed in Germany under war stress. The Germans had no crude oil, but they had available and used some of the fuels in Table 1.

TABLE 1—HEAT VALUES AND AIR REQUIREMENTS OF VARIOUS AUTOMOTIVE FUELS[4]

Fuel	Illustrative Analysis, per cent					Average Lower Heat Value, B.t.u. per lb.	Theoretical Air Requirement per Lb. of Fuel, lb.	Boiling Point, deg. fahr.	Heat of Evaporation, B.t.u. per lb.
	Carbon	Hydrogen	Nitrogen	Oxygen	Sulphur				
Coke Oven Tar[5]	89.45	6.59	....	3.96[9]	....	14,700-15,700	12.3	...	...
Commercial Benzol	91.50	7.80	....	.....	....	17,300	13.3	176	167
Creosote Oil	80.11	9.70	8.90[10]	.....	1.30	15,600	12.5	...	...
Crude Oil	84.00	12.00	....	1.00-4.00[9]	....	17,000-21,000	13.9	...	...
Ethyl Alcohol[6] 95%	52.12	13.14	....	34.74	....	10,800	8.6	172	372
Ethyl Alcohol[7] 90%	52.12	13 14	....	34.74	....	10,200	8.2	172	372
Fuel Oil	86.30	12.50	....	1.20[9]	....	18,000+	14.0	...	...
Gas Oil	86.30	12 65	....	.....	....	18,000	14.4	300-750	300[11]
Gas Tar	89.45	6.59	....	3.96[9]	....	14,700-15,700	12.3	...	...
Gasoline	85.10	14.90	....	.....	....	18,000	15.0	140-437[12]	150
Kerosene	85.20	14.12	0.60[10]	.....	....	19,000	14.8	292-600[12]	250[11]
Methyl Alcohol	37.50	12.50	....	50.00	....	8,400	6.5	150	480
Naphthalene	93.75	6.25	....	.....	....	17,300	13.0	422	..
Sulphuric Ether	65.00	13.50	....	21.50	....	15,900	11.3	96	162
Toluol	91.50	8.50	....	.....	....	18,300	13.5	232	150
Water Gas Tar	91.00	7.40	1.60[10]	.....	....	16,200	13.0	...	...
Xylol[5]	90.60	9.40	....	.....	....	18,500	13.8	288	146

[4] From a bulletin of the Ohio State University.
[5] From dry distillation especially in vertical retorts.
[6] 95 per cent by weight. The composition given is that of pure 100 per cent alcohol.
[7] 90 per cent by weight. The composition given is that of pure 100 per cent alcohol.
[8] Approximate average.
[9] Total of nitrogen, oxygen and sulphur.
[10] Total of nitrogen and oxygen.
[11] Including heating of the liquid above average atmospheric temperature.
[12] Present end-point in Government specifications.

Gas oil is available in this country in small quantities and we throw it away. The gas works use it to enrich illuminating water-gas, but there is no need of this. In former days, when we used open-flame gas-jets, we needed a luminous flame; now we use gas-mantles and want a non-luminous flame. We do not need rich gas for lighting purposes now; city ordinances that require the gas companies to enrich illuminating gas with gas oil are antiquated and unintelligent.

Benzol has been tried out as a fuel by the Germans. It is obtained as a by-product from the manufacture of gas in this country and we get about 4,400,000 gal. per year in this way. As a by-product from coke ovens we secure about 44,000,000 gal., so that the total supply of benzol in this country is about 50,000,000 gal. per year. That could be increased very largely if we coked all of the 500,000,000 tons of coal we use in this country per year. We would obtain 2 gal. of benzol per ton of coal, or 1,000,000,000 gal. or, roughly, 20,000,000 bbl. of benzol, which is much less than we need. We need 100,000,000 bbl. of automotive fuel at the present rate of using it; so, the benzol would supply one-fifth of what we need. Benzol contains less hydrogen than petroleum, develops fewer heat units per pound, requires somewhat less air per pound, is very volatile and boils at 176 deg. fahr. It is a very good fuel so far as those qualities go, but when it is used in internal-combustion engines there are certain things to guard against.

Benzol is apt to contain a substance akin to resin called cyclopentadiene, which has a tendency to close up the fuel passages in time. That is not a very serious trouble but benzol must be purified with acid to eliminate the cyclopentadiene. Another trouble is that benzol dissolves shellac and is likely to dissolve the coating on the carbureter float. For that reason the float should be made of metal. If a low compression pressure is used, benzol tends to form a fluffy carbon deposit in the cylinders. That is not serious if a higher compression is used than is customary with gasoline; it is eliminated entirely if benzol and alcohol or gasoline and benzol are mixed. There are varying statements regarding carbon deposits when using benzol as fuel. The National Automobile Chamber of Commerce made an investigation during the war by running a six-cylinder Continental engine on benzol. There was no trouble from carbon formation; the engine ran very economically and generated more power than it did on gasoline. Thomas Midgley, Jr. and others say they have trouble with this fluffy carbon in low-compression engines; so, one must be prepared for such trouble if these engines are used. Benzol is being used in this country and in Germany to a considerable extent at present.

The farmer has been told that he could use his corn and potatoes, corn-stalks and the like, by turning them into alcohol. In the city, garbage can be converted into alcohol successfully. Anything that has starch of sugar in it can be turned into alcohol. One bushel of potatoes will make about ¾ gal. of 95-per cent alcohol and we could get 2 bbl. of alcohol from an acre of potatoes if about 110 bu. per acre were raised. In Maine they grow 400 bu. of potatoes per acre. At the rate of 2 bbl. of alcohol per acre of potatoes, 50,000,000 acres would have to be used to produce alcohol enough to supply the automotive needs of the country; which is not a very large acreage. The total farm acreage in the United States is over 800,000,000 acres, and the cultivated acreage is between 400,000,000 and 500,000,000 acres. So, it would amount to taking about 5 per cent of the farm land, or 10 per cent of the cultivated farm acreage, and utilizing it for producing alcohol for internal-combustion engine fuel.

One bushel of corn will yield 2.7 gal. of 95-per cent alcohol. If 28 bu. of corn per acre are grown, we can again get 2 bbl. of alcohol per acre. That may be a larger figure than the average yield of corn per acre for the entire country, but it can be obtained. There again we would need 5 per cent of the farm land or 10 per cent of the cultivated farm acreage to plant to corn to be turned into alcohol. From the standpoint of acreage that would be satisfactory but from the standpoint of price it is not. If we desire to buy alcohol at 40 cents per gal., potatoes must be sold for 15 cents and corn for 50 cents per bu. That would not please the farmer. It has been suggested that waste potatoes and culls be used for this purpose, and that probably is the only method we could countenance in the United States. The situation is different in Europe. During the war gasoline cost nearly $2 per gal. in most of the European countries; it cost over 4 shillings in England. Under such conditions of price it is profitable to turn potatoes and corn into alcohol.

Could we not turn waste products such as straw into alcohol? It is possible to convert 10 per cent of the wheat straw into alcohol. If we figure 1 ton of straw to every acre of wheat land in the country, that gives about 40,000,000 tons of straw available for making alcohol. It has been estimated that 20,000,000 bbl. of alcohol could be produced from the straw. Some people have thought this is the solution of the problem. Henry Ford is building a plant at Detroit to produce alcohol from straw. The trouble is that the straw cannot be left until the kernel of the grain ripens. Straw loses one-half of its alcohol-yielding properties when it becomes dry. Another obstacle is the high cost of collecting the straw from large areas to produce alcohol in vast quantities. While it may not be profitable to turn straw into alcohol, it may be possible to turn the straw into gasoline, although hardly for other than stationary-engine use.

Sulphite liquor is obtained in paper mills as a by-product from cellulose that is manufactured into paper. The alcohol we could get from that source amounts to less than 1,000,000 bbl. Sawdust has also been turned into alcohol in Europe. The sawdust is treated with sulphuric acid. The total amount of sawdust available from all the sawmills in the United States would yield less than 1,000,000 gal. of alcohol.

A most interesting way to produce alcohol from coal has been developed in Europe. Calcium carbide, which is a combination of limestone and carbon, is produced first and by the action of water acetylene is obtained. The next process produces aldehyde and alcohol is produced finally. That is the way they do it in Switzerland. At the prewar rate of exchange the cost is less than 30 cents per gal. Yet the prewar power cost was high, about ½ cent per hp-hr., but coal was higher, about $8 per ton in this calculation. It appears to be a good proposition in that it requires only coal, limestone, water vapor and some sulphuric acid to produce alcohol. This has been done commercially abroad. The Swiss Government has control of the companies that produce in this way. We could do that here but we would need about 16,000,000 hp. to produce all the alcohol we need to run our automotive apparatus. The total water-power of the country has usually been estimated at 25,000,000 hp. on an all-year basis. On a six-months' basis we have 50,000,000 hp.; so, it is feasible to do this.

Alcohol itself attacks iron and copper worse than benzol does; it contains a certain amount of water and that corrodes the fuel ducts. If a rich mixture contain-

ing alcohol is used, combustion will develop acetic acid and aldehyde and that may corrode the cylinders. When using alcohol, the fuel tanks and fuel ducts should be lead-lined and precautions taken against running on an over-rich mixture. The London General Omnibus Co. found the mixture of alcohol and benzol satisfactory in London. We would not find it satisfactory here because it gives a less number of miles per gallon in winter than gasoline. Roughly, only 6 miles per gal. can be obtained with alcohol and benzol mixed half-and-half, as compared with more than 7 miles per gal. on gasoline. Alcohol has the advantage of being a very fine carbon-remover.

Naphthalene is a solid but melts at 68 deg. fahr. Mixing it with benzol, for instance, gives a liquid fuel that operates very well. It is being used in Paris. Only small quantities of naphthalene are available. Ether is of some interest as an engine fuel. It has the same chemical constituents as alcohol. The only difference is that it has a boiling point of 96 deg. fahr.; alcohol has a higher boiling point. Ether mixed with alcohol makes a mixture that starts an engine easily in cold weather. It is sold in England under the trade name of Natalite. Some official results of tests by the Royal Automobile Club of Great Britain show that it is a very good fuel. Ether is produced from alcohol by the action of sulphuric acid and so costs more than alcohol. In South Africa Natalite sells for 3 shillings per gal. as against 4 shillings for gasoline.

As an engine fuel benzol has a very unpleasant property; it solidifies at 40 deg. fahr. Toluol and xylol are substances nearly akin to benzol and are obtained in the same process. If they are mixed with benzol, the freezing point is lowered somewhat. It is lowered still more by mixing gasoline with alcohol. A fuel mixture that solidifies at about 4 deg. fahr. is secured. This is what Germany used during the war. The best test information we have is to the effect that in Germany a mixture of one part of alcohol, one part of benzol and one part of kerosene gave better results in economy and power than any other fuel in existence. It was better than gasoline and better than benzol and alcohol. It is the fuel especially recommended by Professor von Loew, who has conducted most of the tests in Germany.

With a fuel that contains alcohol and benzol the engine compression can be increased. If this is done with the present-day gasoline or kerosene, a knock is produced. Alcohol and benzol will not produce a knock. They burn slowly. For that reason the compression can be increased to 200 lb. per sq. in. When that is done, better power can be obtained from the alcohol mixture than from gasoline. If we increase the compression in engines, provide a lead lining for the fuel ducts and see to it that a lean mixture is used, there is no reason why we cannot run an engine on a mixture of benzol and alcohol; or benzol, alcohol and gasoline; or alcohol and ether; and, perhaps other mixtures, obtaining as good results as we do now from gasoline. However, as I have tried to point out, the obstacles that prevent the utilization of these possibilities are their excessive cost and the enormous quantities we need. The best we could do is to produce alcohol by utilizing our water-power, and benzol from all the coal we use. Even so, however, it would be hard to produce enough of the two to meet our automotive needs. Important quantities could be produced if the emergency arose, but I do not think this will ever be necessary.

Shale Oil

There is a resource from which we can get all the fuel we need in this country and at no unreasonable price. It is oil shale. I do not give my own unsupported opinion. Victor C. Alderson, president of the Colorado School of Mines, has made oil shales his life study. He has been criticized as over-optimistic, but his figures are worth something. I quote from a circular he issued that covers the status of oil shale in 1920 and gives the latest information on the subject.

> There are enormous deposits of oil shale in the United States. The shale contains a substance called "kerogen," which when heated is distilled into oil. By retorting this oil shale, oil is obtained in varying quantities. Tests in Colorado have given an average yield of about 20 gal. per ton of shale. However, there are deposits that yield 50 gal. per ton of shale and in some cases 90 gal. Shale in Canada has been tested that yields 120 to 130 gal. per ton of shale. The rich shale will be the first to be worked for commercial purposes. We have all kinds of shale in Colorado; enough to yield about 20,000,000,000 bbl. of oil, so far as we know. According to the best estimates of the United States Geological Survey, there is enough shale in southwestern Indiana to yield 100,000,000,000 bbl. of oil. New deposits have been discovered recently in California which are of considerable importance. In other words, shale will provide oil resources to last for many generations. We were all interested in shale oil during the war. The Government made some investigations and so did other organizations, but we must tackle the problem in earnest and learn the methods of working oil shale. We must create new methods. It must not be forgotten that to supply our automotive fuel needs, we must mine as much shale as we now mine coal. The development of this immense industry is a tremendous problem, but we shall have from 15 to 30 years in which to work it out. We should start right now, and learn how to retort the shale, so as to utilize the oil it contains.

At present such firms as the Standard Oil Co., the Ohio Cities Gas Co. and other large financial interests have bought a large number of shale properties and we have shale-oil plants operating on a commercial basis. The Catlin plant at Elko, Nev., has produced oil from shale at a price of $1.25 per bbl. of oil. That would be about 3 cents per gal., a great difference from 30 cents per gal. for gasoline. E. W. Hartman, president of the United States Producers Refining Co., which has bought about 1000 acres of oil land in California, estimates that his company can obtain shale oil for 65 cents per bbl., which is very much less than we are paying for crude oil in the Mid-Continent field. Plants are being erected throughout the West and commercial research is being carried out.

Even so, however, there is less enthusiasm over shale oil in this country than in England, in spite of the fact that they are having trouble there. They have rich shale deposits, but this shale contains sulphur. The problem for England is how to remove the sulphur and that is difficult. To solve it the University of Birmingham has obtained donations of not less than $625,000 through various oil companies in England to carry out research work on how to remove sulphur from shale. We have no such trouble in this country with the oil shale. Our trouble is that perhaps some interests will continue to advocate obtaining crude oil from South America and that we will neglect the production of shale oil in this country on a commercial basis. On the whole I can hardly do better than to quote verbatim the optimistic conclusion of Mr. Alderson.

> Close observers have known of the possibilities of oil shale for years, but not until the past year have laymen, investors, oil men, mining men and the large financial interests become awakened to the full import

of the subject and its great possibilities. The action of such strong financial organizations as the Union Oil Co. of California, the Pure Oil Co, the Ohio Cities Gas Co., the Carter Oil Co., the Standard Oil Co. and the Midwest Oil Co. in the United States; the Anglo-American Co. and the Anglo-Persian Oil Co. of London; and the Var Coal & Oil Co. of France, in acquiring land and investigating the method of treatment of oil shales, points unerringly to the early establishment of the industry on a commercially productive basis, so that the United States need have no apprehension whatever about its domestic supply of crude oil, virtually for all time.

THE DISCUSSION

W. G. CLARK:—With a mixture of alcohol, kerosene and benzol, what engine compression is used?

PROF. C. A. NORMAN: — Mixtures like that have been tried out by the London General Omnibus Co. The final compression used was, I think, about 120 lb.

MR. CLARK:—When you said that this mixture of alcohol, kerosene and benzol is superior to gasoline, did you mean that it is superior in the same engine?

PROFESSOR NORMAN:—The data I have seen do not cover this point explicitly, but my impression is that the same car and engine are meant.

MR. CLARK:—In a mixture such as that do the detrimental effects of benzol as regards the attacking of the metals still remain in the mixture, or does the mixture of these different fuels eliminate that effect?

PROFESSOR NORMAN:—I think that would have to be guarded against to some extent. Some of the effects are due to the water that is in the alcohol and the benzol. It is possible that the water would tend to separate out and that the corrosion would be reduced on that account; but, if the benzol is not pure, for instance, polymerization will occur and clog up the fuel passages.

A. F. MOYER:—Are not some of the substances such as benzol of great value for producing mixtures with lower grades of fuel? I have in mind a 3 to 1 kerosene-benzol mixture I tested. In the actual operation of the engine one could not distinguish the difference between that fuel and the ordinary low-test gasoline. The engine would start as well and run with about the same fuel consumption per horsepower-hour. If we could utilize some of the low-grade fuels by mixing benzol with them it would be a perfectly commercial proposition.

PROFESSOR NORMAN:—I think it would be a commercial proposition, but the question is whether benzol could be produced on a large scale. Only about 1,000,000 bbl. of benzol is available at present; I think it would not have a very great effect on the fuel situation generally. It might be an important consideration in the tractor situation. I think the tractor consumption of gasoline amounts to not more than 5,000,000 to 10,000,000 bbl. of gasoline per year.

MR. MOYER:—I understand that research work is being carried on in coking processes that will greatly increase the supply of light fuels from that source. The vapor pressure is the property of fuel that determines the quality of vapor-air mixtures. The vapor pressure of a mixture of liquids may be equal to the sum of the vapor pressures of the individual constituents. This may be true of dissimilar substances such as benzol and kerosene. We could mix with such fuels as benzol, alcohol, etc., large proportions of low-grade petroleum products and thereby increase our fuel supply.

PROFESSOR NORMAN:—The production of a greater quantity of benzol from coke is a simple matter of temperature. If the coking process is continued to very high temperatures, it results in a large quantity of permanent gas, some naphthalene and a very small quantity of oil; at lower temperatures various other products are obtained. I do not know what could be done in that respect. Much work has been done on this in England. As to vapor pressures, in many cases the amount of vapor tension can be increased by mixing in other substances. For instance, the vapor tension of benzol and alcohol together is considerably greater than the vapor tension of the two taken separately.

MR. CLARK:—Is not that also the reason for the advantage claimed for certain substances advocated as ingredients to put in fuel tanks in small quantities to increase the efficiency?

PROFESSOR NORMAN:—There is a patented substance of the General Motors Research Corporation that works in that way. What we desire is to increase the economy and the power of the engine by increasing the compression without introducing any undesirable feature. With kerosene, the engine compression is 60 lb. per sq. in.; with present-day gasoline the compression is 70 to 80 lb. per sq. in. Gasoline is becoming of worse quality continuously. It has been found that if about 3 per cent of anilin or iodine is added to gasoline fuel, the mixture prevents cylinder knock. The explanation is complicated. It is given in a paper[13] by Thomas Midgley, Jr., entitled Combustion of Fuels in Internal-Combustion Engines. Anilin or iodine can be mixed with gasoline to obtain higher compression and get better economy from the fuel. The question arises whether it is economical to produce enormous quantities of anilin to enable us to construct more efficient engines. My attitude is that we ought to construct an engine that will utilize the fuels as they are more efficiently. It may even be impossible to produce the enormous quantities of anilin we would need.

L. F. OVERHOLT:—How are alcohol and kerosene mixed to make them combine?

PROFESSOR NORMAN:—Kerosene and alcohol do not mix well. However, if about 7 or 8 per cent of benzol is first mixed with the alcohol, it acts as a binder when the kerosene is added.

DRY AND WET MIXTURES

I. L. JOHNSON:—In using kerosene and alcohol should the mixture be dry when it enters the cylinder or slightly wet? We believe that it should not be too wet, but that some dampness will give better results in actual horsepower.

PROFESSOR NORMAN: — There is some difference of opinion as to whether one should use a wet or a dry mixture. I believe in a dry mixture. If the air is heated, this has a tendency to reduce the power to some extent. The Bureau of Standards has made tests along this line. Keeping the air cool to allow the fuel to enter wet, gives more power; but, when driving on the road, the more the mixture that enters the engine is heated, the better the acceleration becomes. From the view-point of general reliability of the engine, freedom from carbonization trouble and crankcase dilution, it is better to run a dry mixture. We know that we get better acceleration from a dry mixture, even if we do not get as much power on block test; so, I am in favor of a dry mixture. It is believed in England that a dry mixture is the best.

MR. CLARK:—Maximum power is a thing we do not deal with or use in the automobile. Automobiles are overpowered. Dry mixtures are by far the best performing mixtures for automobile work. The tractor is a form of automotive apparatus in which maximum power is a

(*Concluded on page* 203)

[13] See THE JOURNAL, December, 1920, p. 489.

Relation Between Fluid Friction and Transmission Efficiency

By NEIL MACCOULL[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

THAT all of the variable factors of automobile friction-losses such as the quantity and viscosity of lubricants, the efficiency of worm-gearing and part-load modifications are not appreciated, is indicated by an examination of the literature on this subject which reveals a lack of necessary data. Experiments to determine the mechanical losses, including all friction losses between the working gases in the engine and the driving-wheels of the vehicle, are described and supplementary data are included from Professor Lockwood's experiments at Yale.

Three distinct possibilities for increasing the fuel economy of a motor vehicle are specified and enlarged upon, gearset experiments to secure and develop data for a four-speed gearset being then described and commented upon at length; photographs and charts illustrative of the equipment used and the resultant data are included. The effects of varying the speed under no-load and load conditions are studied, inclusive of mathematical analysis, and the efficiency of the gearset and noise measurements made in regard to it are discussed. The paper is then summarized.

ALTHOUGH means of minimizing thermal losses in motor-vehicle engines have received a certain amount of study, very little attention has been given to the mechanical-friction losses of the engine and the transmission system. Mechanical friction is usually thought of as a necessary evil, and has been dismissed without much further analysis. An examination of the literature on tests of automobile-friction losses shows, by a lack of certain data, that all the variables were not thoroughly appreciated. For instance, as data given later in this paper will show, the quantity and viscosity of the lubricants used have a pronounced effect on the magnitude of the losses; yet most experimenters do not take this into consideration, and few even mention data from which oil viscosities can be computed. Again, the elaborate experiments on the efficiency of an automobile worm-gear published by the Department of Scientific and Industrial Research, of Great Britain, failed to give data by which losses at other than full load can be estimated. In fact, most experiments are made at either full load or full speed, apparently unmindful of the fact that a motor vehicle operates only occasionally under such conditions.

The term "mechanical losses" as used here includes all friction losses between the working gases in the engine cylinders and the driving-wheels of the vehicle. The only "useful work" done by an engine and its transmission system on a level road is in overcoming the resistance of tires and wind-pressure. In reality, the tire resistance is a part of the complete transmission system, but it is not a mechanical part of that system. Therefore, a mechanical efficiency of 100 per cent would mean that the indicated power of the engine would be equal to the sum of the tire and wind-pressure resistances only. The magnitude of the useful force necessary to propel a typical touring car of 4500-lb. weight at various speeds on smooth level ground, in terms of drawbar pull or towing resistance, is shown below the datum line of Fig. 1. Above the datum line, the mechanical losses of the separate units of the car are shown in terms of propeller-shaft torque. The data are computed from experiments of Prof. E. H. Lockwood at Yale, and the experiments are described later in this paper. Cord tires pumped up to a pressure of 65 lb. per sq. in. were assumed. Fabric tires under the same conditions would have nearly double the resistance, and both would have considerably greater resistance with lower air-pressure.

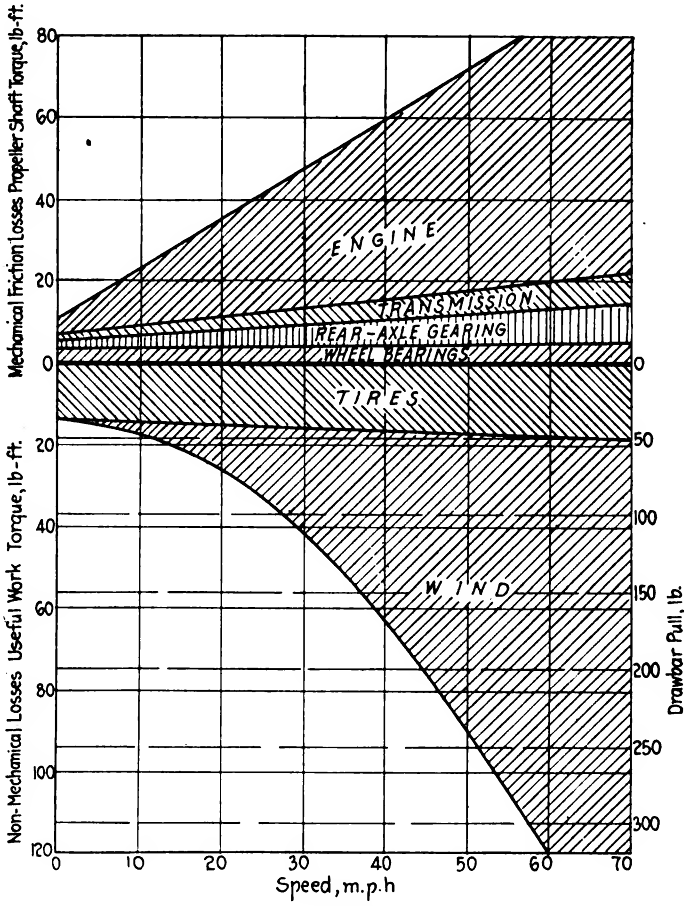


FIG. 1—DIAGRAM SHOWING THE MECHANICAL LOSSES IN A TOURING CAR WEIGHING 4500 LB. AND THE MAGNITUDE OF THE USEFUL FORCE NECESSARY TO PROPEL THE CAR AT VARIOUS SPEEDS

An examination of the items comprising the losses shown in Fig. 1 suggests three distinct possibilities for increasing the fuel economy of a moter vehicle.

(1) A suitable relation between gear-ratios and engine will reduce the well-known engine losses due to extensive throttling at average car speeds
(2) Reduction of vehicle weight
(3) Reduction of mechanical-friction losses

[1] M.S.A.E.—Automotive engineer, Texas Co., New York City.

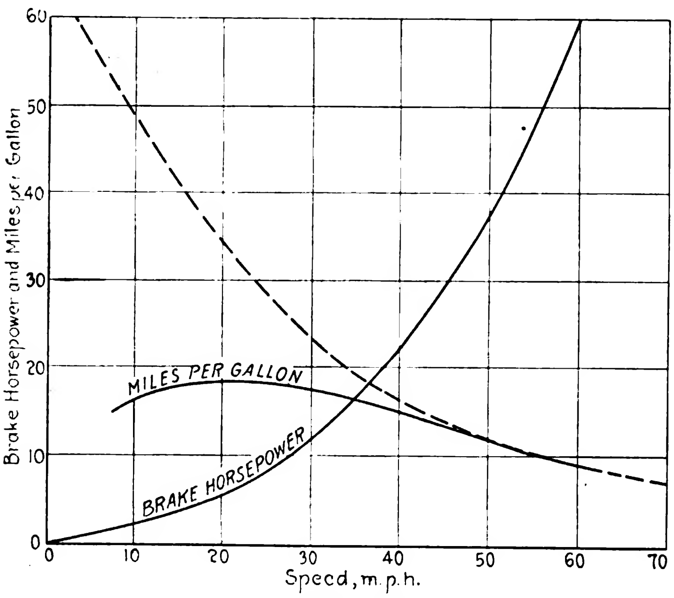


FIG. 2—HORSEPOWER AND GASOLINE-MILEAGE CURVES FOR A 4500-LB. TOURING CAR AT VARIOUS SPEEDS

In Fig. 2, the horsepower, calculated from Fig. 1, to propel the car at various speeds on a level road, which checks well with actual tests, is shown, as well as the gasoline mileage at various car speeds, which has been determined experimentally for a similar car under ideal conditions on a speedway. At the lower car speeds, much greater fuel-economy would be realized except for the very low mechanical and indicated thermal efficiencies of an engine when throttled to develop but a fraction of its normal torque. As a matter of interest, the dotted curve is given to indicate the fuel economy that could be realized if the fuel consumption per brake horsepower developed were the same at fractional as at full load. Similar results could be obtained if the engine power were no greater than just sufficient to drive the vehicle at the speed at which the economy is indicated. For instance, if the throttle had to be opened wide to make 25 m.p.h. on a level road, either because of a small rear-axle reduction or a small-sized engine, it would be possible to secure 28 miles per gallon of fuel at that speed, and better at lower speeds.

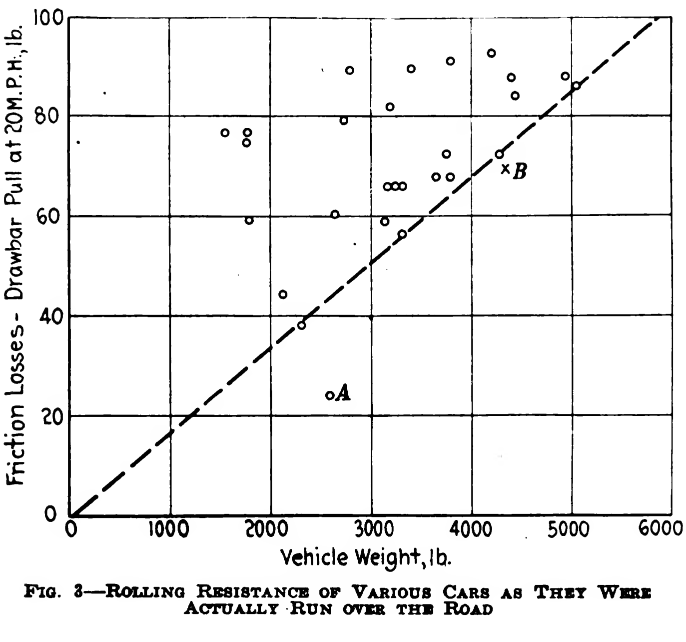


FIG. 3—ROLLING RESISTANCE OF VARIOUS CARS AS THEY WERE ACTUALLY RUN OVER THE ROAD

Fig. 3 shows some of Professor Lockwood's data in regard to the rolling resistance, excluding wind resistance, at 20 m.p.h., of various cars taken from the road in the actual condition in which they were run by their owners. The variation of resistance with weight is evident, as well as the superiority of some cars over others of the same weight. Notice the exceptionally low resistance of car *A*, which made 82 miles on 1 gal. of fuel on an official road test. Point *B* represents the car assumed in Figs. 1 and 2.

The question upon which it is attempted to focus attention here is, Why have some vehicles so much less frictional resistance than others of the same weight? If the distribution and cause of all these losses were known, it seems reasonable that all cars might be made with no greater resistance than those that fall on the dotted line, and even better might eventually result. Such data are food for much thought among those who wish to produce vehicles with really high fuel-economy. An analysis of these losses can be made only by isolating the individual units and examining each separately.

GEARSET EXPERIMENTS

Methods taken to secure and develop this information for a four-speed gearset, and some of the results secured, are described in this paper. The data are not at all complete because of lack of time, but it is believed that the general trend of the results, even though unchecked, will be of interest to the profession. The magnitude of the task is indicated by the fact that the six variables of gear-ratio, revolutions per minute, oil type, oil temperature, oil level, and load, were dealt with. No satisfactory method was available for separating the bearing losses from the gear losses and, to do so, separate bearing tests must be made. This investigation did not cover the results of varying the gear-pitch, tooth-shape and tooth hardness, or the very important feature of wear.

The two gearsets tested were standard four-speed frame-type Brown-Lipe truck transmissions, rated for 35 hp. at 1000 r.p.m. The construction and principal dimensions can be seen in Fig. 4 and the gear-ratios in Table 1. The gears are of 5-per cent nickel steel, case-hardened and of 6/8 pitch. Timken taper roller-bearings were used throughout. A sheet-metal case, for water or brine and ice mixtures to control the temperature, was placed around each gear case. Thermometers were located as shown, to measure the temperatures of the oils near the center of their masses.

TABLE 1—GEAR-RATIO OF THE GEARSET TESTED

Speed	Teeth of Engaging Gears	Total Reduction
Reverse	18-33—16-13—16-35	4.81
First	18-33—16-35	4.00
Second	18-33—21-30	2.62
Third	18-33—28-23	1.50
Fourth	....	1.00

APPARATUS LAYOUT

For the sake of greater accuracy, the friction losses were measured directly instead of being calculated as the difference between power input and output. For this purpose an unusual set-up was made in which two similar gearsets were bolted together rigidly with the propeller-shaft ends coupled together. Thus, if both units are in the same gear-ratio, the shafts *a a*, which are normally connected to the engine, both turn at the same speed, since the speed-reduction of one gearset will be

compensated for by a similar step-up in speed in the other. The unit consisting of both gearsets was suspended from each end on two ball bearings that acted as rollers, as shown in Figs. 4 and 5, and was free to swing or oscillate about the shaft centers. It is evident that, if the input and output torques are not equal, the difference between them will manifest itself as torque tending to rotate the unit; and the magnitude of this torque can be read directly on a spring-scale fastened on an arm bolted to the unit, which resists this torque. Since the speeds of the shafts transmitting power to and from the unit are equal, any difference between their torques will show directly the torque loss due to friction in the two gearsets. By measuring the losses directly in this way rather than by subtracting the power absorbed by the brake from the power of the engine, much greater accuracy was obtained, since errors of observation are normally large in comparison with the power losses involved.

Power was supplied by a 150-hp. Sprague cradle-dynamometer used as a motor, and the load was applied by a Froude hydraulic brake. These two units were coupled to the gearset unit by short lengths of shafting and semi-flexible couplings of the Clark type supplied by the I. H. Dexter Co. They were in reality thin chain-sprockets tied together by roller chains, and allowed enough flexibility to reduce very materially the labor of lining-up.

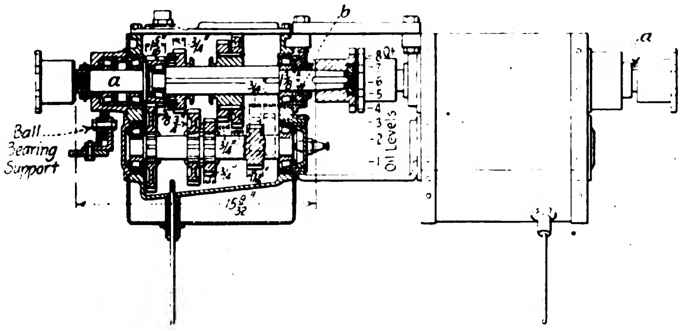


Fig. 4—Construction and Principal Dimensions of the Two Gearsets Tested

Figs. 5 and 6 show the set-up of all of the apparatus. On the end of the arm carrying the spring-scale for reading the power losses, a dashpot was improvised by suspending a weighted disc of metal in a pail of gear oil. At the other end of the arm, weights were suspended so as to counterbalance partially the weights of the scale and disc in the dashpot. The power losses for one gearset were assumed to be one-half the losses read. This involves a small error because the power input of the second gearset is not as great as that of the first, the difference being the power lost in the first, but it is too small to consider.

Test Routine

When first set up, the gearcases were filled with kerosene and run for a short time at low speed to wash out any chips or other foreign matter. After running only a few minutes, one of the bearings began to squeal and soon bound tightly enough to stall the motor, which was drawing only enough current to turn over at a speed of a few revolutions per minute. Reversing the motor loosened the bearings for a few turns only; the same squealing and binding then reoccurred. This was true whether the gears were in neutral, direct or in gear, and was not helped by backing off the bearing adjustment. All trouble ceased when the kerosene was drained and a few drops of light machine oil were run on the bearings, proving that roller bearings certainly must have a better lubricant than kerosene.

Fig. 5—The Two Gearsets as Arranged for Testing

It will be noticed that one gearset always runs in a direction opposite to normal. This reverses the action of the oil seal provided for the engine shaft, which consists of a helical groove cut in the bearing retainer where the engine shaft passes through. Simple as this seal is, it is so effective that oil seldom leaked through from the gearset running in the normal direction, while the other gearset leaked a steady stream. Advantage of this feature was taken in cleaning the gear cases when changing from one oil to another. After draining, they were filled with kerosene and run in one direction until there had been sufficient leakage at one seal, and then reversed for leakage at the other seal. This assured the removal of most of the oil from the space between the engine-shaft bearings. No trouble was experienced with binding bearings because of lubricating oil which dissolved in the kerosene. After draining the kerosene, the cases were dried and filled with the oil next to be tested, the gears were run first in one direction and then in the other to assure getting the new lubricant to all bearings, and then the oil was drained to the proper level. Normal oil-level represented 4 qt. in each case. The oil levels resulting from various quantities of oil are shown to scale in Fig. 4.

It was not easy to clean the gear cases even in this way after using greases, since the latter are almost in-

Fig. 6—General View of the Apparatus Employed in the Tests

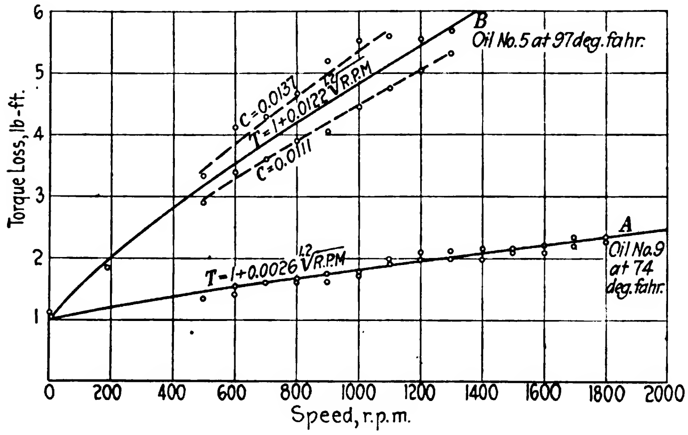


FIG. 7—CURVES SHOWING THE LOSSES AT DIFFERENT SPEEDS WHILE ACCELERATING AND DECELERATING

soluble and must be dug out of the corners. It is easy to believe that automobile operators would not be very thorough in cleaning out cases filled with old grease, and sediment and chips lying near the corners might be left to mix with new grease. This is a strong objection to the use of any grease that does not possess sufficient fluidity to drain out by itself.

TEST RESULTS

Except where specified, all runs were taken at 1000 r.p.m., second gear and with 1 gal. of oil in each gear-case. By taking readings of losses at different speeds while accelerating and again while decelerating, so that a whole series covered less than 1 min., it was possible to discount the effects of temperature changes because the oil temperature at the end of a series was but 1 or 2 deg. higher than at the start. As might be expected, the readings taken while accelerating are higher than while decelerating but, at low temperatures, with very viscous oils, the differences are greater than can be accounted for unless the temperature of the oil adjacent to the moving surfaces became heated locally above the normal temperature of the remainder of the oil. Most of the runs showed a fair agreement of accelerating and decelerating data as indicated by curve A in Fig. 7, and

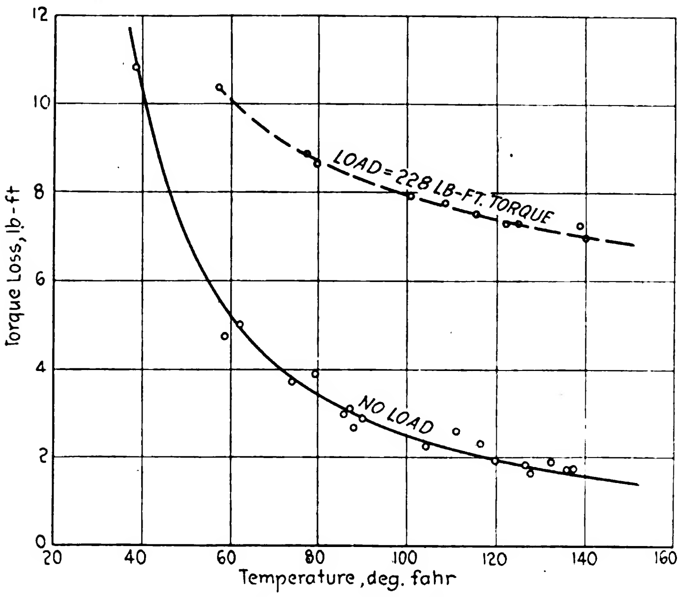


FIG. 8—TYPICAL DATA FOR A RUN WITH ONE OF THE OILS TESTED

an average was assumed as the true value. These curves followed an equation of the form:

$$F = K + C\sqrt[1.2]{(S)} \qquad (1)$$

where

C = a constant
F = friction loss in pound-feet of torque
K = a constant, varying with viscosity and oil level
S = speed in revolutions per minute

One of the most interesting results of these experiments was the discovery of the constant K, which is equivalent to a starting friction that must be overcome before motion begins and in addition to all losses varying with the fluid friction of the lubricating oil. It is not certain what the cause is for the existence of this starting friction, for one does not associate roller bearings with this characteristic of plain bearings. There is a possibility that it is due to the compression packing on the main shafts, shown at b in Fig. 4, that is used to prevent oil leakage, although this was not investigated. The constant C varies with the viscosity of the lubricating oil as will now be shown.

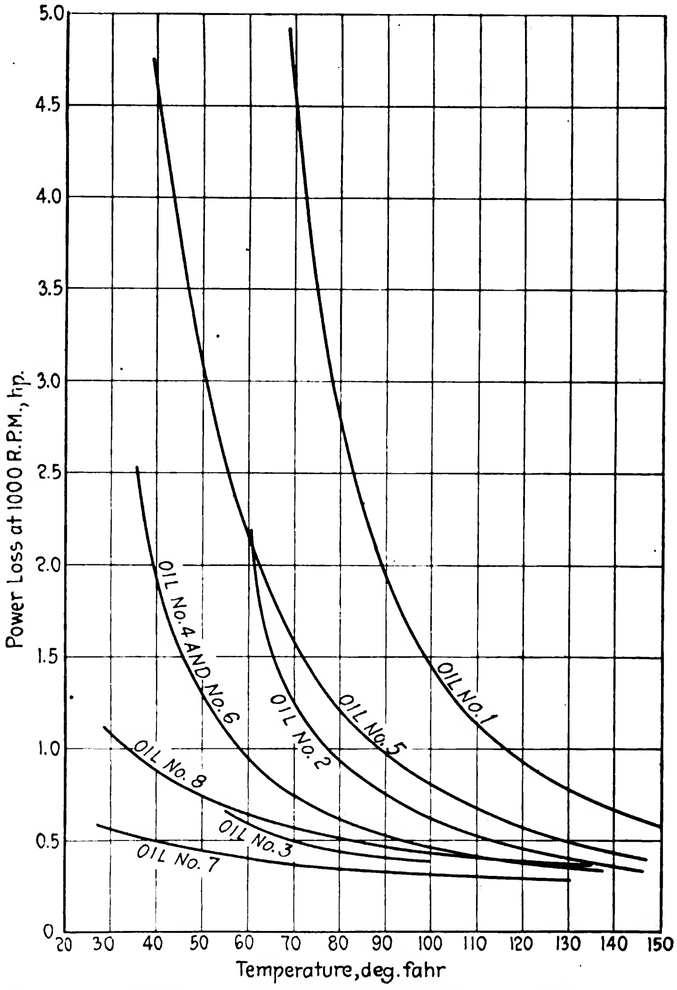


FIG. 9—A COMPOSITE CURVE OF THE CORRESPONDING NO-LOAD LOSSES FOR DIFFERENT LUBRICANTS EXPRESSED IN TERMS OF HORSEPOWER

To determine the effect of temperature changes, the lubricant was chilled by packing the jackets with crushed ice and calcium chloride. The time required was much longer than was expected, especially when the temperature of the lubricant neared the pour-point. In one instance, a temperature of 20 deg. fahr. below zero was maintained for nearly 3 hr., yet the oil temperature was lowered only to 29 deg. fahr. The first readings were

taken as soon as the motor speed was brought up to 1000 r.p.m. The motor was then stopped while the oil temperatures were read. The average reading of the thermometers in each gearcase was used in plotting the results. At the lower temperatures, the oil temperatures rose so rapidly at this speed that it was difficult to take readings with fair accuracy. Readings were taken in this way at intervals as the oil temperature rose. After a few such readings, the rise of temperature was hastened by

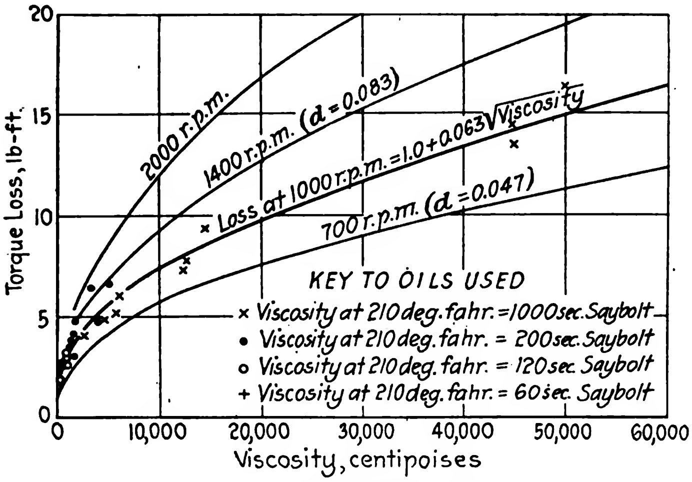


FIG. 10—CURVE SHOWING THE NO-LOAD LOSSES FOR DIFFERENT LUBRICANTS PLOTTED IN TERMS OF VISCOSITY

adding warm and then hot water to the jackets. Fig. 8 shows typical data from such runs for one oil, and Fig. 9 is a composite of the corresponding no-load losses found for different lubricants under the same conditions but expressed in terms of horsepower. It is evident how valueless any gear-efficiency tests may be without a record of either the oil or its temperature. Fig. 10 shows the data of Fig. 9 plotted in terms of the viscosity of the oils instead of their temperatures, which is really the information desired in such a test. The curve gives results that are useful in terms of a formula for any oil, since charts similar to Fig. 11 are available to show their temperature-viscosity relations. The heavy curve of Fig. 10 was plotted to an equation of the form:

$$F = K + D\sqrt{(V)} \qquad (2)$$

where

D = a constant
F = friction loss in pound-feet of torque at 1000 r.p.m.
K = a constant
V = viscosity in centipoises

The constant K seems to be the same as that appearing in equation (1), although one would expect it to vary with the number of revolutions per minute. The variation of the constant D with different oil-levels will be shown later.

The losses with oil No. 5 are consistently higher for corresponding viscosities than those of the other oils. It is believed that this was due to the presence in the pocket between the engine-shaft bearings of some of the very viscous oil, No. 1, that had been tested just previously. This would be a likely source of error if the washing with kerosene were not complete. The curves shown as light lines in Fig. 10 were computed from equations (1) and (2) for a number of revolutions per minute other than the experimental readings at 1000 r.p.m. Equation (2) was used to correct much of the following data to equivalent readings at some one temperature,

[3] See Report of National Physical Laboratory for 1913-1914, p. 101.

FIG. 11—TEMPERATURE-VISCOSITY RELATIONS OF A NUMBER OF LUBRICATING OILS

since the oil temperature varied somewhat during any series of runs taking much time. Equations (1) and (2) can be combined into an equation of the form

$$F = K + [D\sqrt{(V)}]\,.\,[\sqrt[1.3]{(S)}] \qquad (3)$$

where

D = a constant
F = friction loss in pound-feet of torque at 1000 r.p.m.
K = a constant affected by the oil level
S = speed in revolutions per minute
V = viscosity in centipoises

The effect on the power losses at different levels was much less than expected. Experiments[3] made in

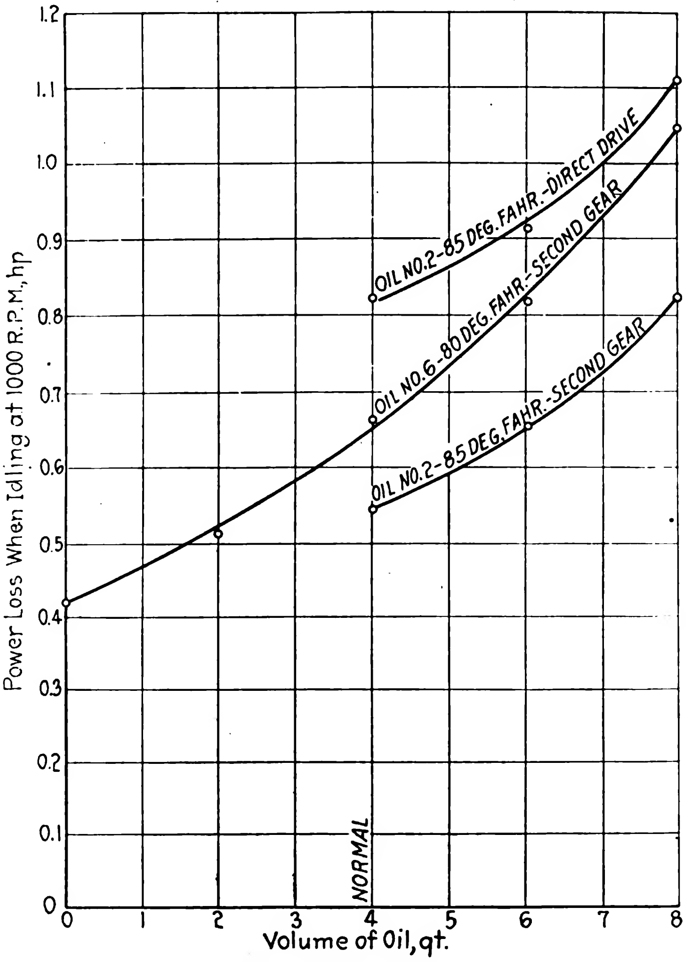


FIG. 12—CURVES SHOWING THE GENERAL RESULTS OF THE TESTS

England with a 32-hp. Leyland gearset on direct drive showed losses at 950 r.p.m. that are stated in Table 2.

TABLE 2—OIL LEVELS AND POWER LOSSES

Oil Level	Power Loss, hp.
¼	0.80
½	1.92
¾	3.20
Full	8.30

The results of our experiments were of the nature of those shown in Fig. 12 and failed to show anything like as great a variation. It was difficult to secure concordant data in this series of runs because all oils tested frothed up with air bubbles after a few minutes of running so that the volume was increased materially. It was not uncommon to drain 6 qt. of oil from a gearcase that had been supplied with only 4 qt. The torque loss recorded after all oil was drained from the gearcases consists of the constant loss K plus the viscous losses of the bearings due to the presence of a certain quantity of oil that clung to them. It is interesting to note here that the losses in direct drive are greater than in second gear for a given *engine* speed, although the reverse is true for a given *car* speed. Other experiments, such as those of Fig. 13, at a speed of 1175 r.p.m., showed that the no-load losses were lowest on first gear and increased regularly to a maximum on direct drive.

Losses Due to Load

So far, all losses given occurred while idling. While transmitting power, additional losses occur which are indicated in Fig. 14. All our experiments indicated that there is a straight-line relation between friction losses and load as shown also in Fig. 13 where similar data have been taken from experiments reported for an automobile gearset,[3] and for a steam turbine double-reduction gear.[4]

The intersection of the load line with the ordinate for zero load is, of course, the idling friction loss that has been analyzed and formulated during the preceding study of no-load losses. What determines the slope of this line, however, is not satisfactorily explained and is somewhat a matter of conjecture. It seems to be influenced somewhat by the viscosity of the oil, as indicated by the distance between the curves of Fig. 8. If the slope were constant, these lines would be the same distance apart throughout.

The number of revolutions per minute of the gears seems to have a similar effect, as is shown in Fig. 14, suggesting that the greater the number of revolutions is, the less the slope becomes. The gear-ratio also has its influence; the greater the ratio is, the greater the slope becomes, but this would be expected from the greater tooth-pressures and bearing loads. Light lines are shown in Fig. 14 that represent various transmission efficiencies. The load curves cross such lines, giving the usual characteristic of an increasing efficiency with an increasing load. If the load were continued indefinitely, the efficiency would approach but never wholly equal the efficiency represented by one of these constant-efficiency lines running parallel to it. For the curve representing 1000 r.p.m., this optimum efficiency would be about 98 per cent. Thus, the higher the load is, the higher the efficiency will be until a load is reached where the load curve ceases to be straight and becomes concave upward, a point not reached in these experiments.

Since the efficiency increases with load, it is interesting to know how high a load the gears can carry. When delivering 43.3 hp. at 1000 r.p.m., which represents 227 lb-ft. of torque, the tooth load was over 4000 lb. per lineal in. of face-width and the static fiber-stress was about 67,000 lb. per sq. in. This stress was figured from a formula given by Prof. G. H. Marx as a result of his experiments.[5] Over 50 hp. was carried several times with no signs of distress, which corresponds to a tooth load of 4800 lb. per lineal in. and a fiber stress of over 80,000 lb. per sq. in. Static tests show a breaking load of 18,000 lb. on a ¾-in. face, which corresponds to a fiber stress of 305,000 lb. per sq. in. These figures are so very much higher than experienced in other branches of the engineering profession that they are especially noteworthy. It is probable that failure by abrasion or wear will occur before breakage, but there was no sign of abrasion in these tests. Experiments on the wear of gears loaded to 3668 lb. per lineal in. have been made and the results recently published.[6] In making use of these figures, it must be borne in mind that these loads were all uniform and not fluctuating as would be the case if the drive had been by a four or even a six-cylinder gasoline engine, in which case a similar maximum would result from a lower average load. Notice that the optimum efficiency will be approached at all loads by a reduction of the no-load losses. If there were no losses at no load, the efficiency would remain constant and equal to the optimum at all loads.

Efficiency of the Gearset

When referring to gearset efficiency it is only fair to talk of the efficiency at the loads experienced in operation. This has been done for level-road conditions in Fig. 15, taking the loads transmitted from Fig. 1 as the sum of the wind, tire, wheel-bearing and rear-axle losses at various speeds.

The curves for direct drive at different temperatures are of particular interest because of showing lower efficiency, with the "heavy" gear-oils now popular, than is usually thought of except when in gear. When a vehicle is run only a few miles between stops during cold weather, the oil does not have time to heat up much and may easily be at a temperature no higher than 60 deg. fahr. The shape of these curves at first seems odd, but is explained by the fact that at low speeds the losses increase more rapidly than the load, accounting for the falling efficiency with increased car speed. The phase of rising efficiency with increasing car speed results when the load increases faster than the losses. In addition to the curve given for second-gear efficiency, a dotted curve is given for the same losses, while carrying the full rated torque of the gearset. Since gears are rarely used except with wide-open throttle when climbing hills, this represents more nearly the actual efficiency obtained than the corresponding curve for level-road conditions. A similar increase of efficiency results for direct drive when climbing grades requiring full throttle, but the level-road conditions more nearly represent average conditions.

Noise Measurements

Noise is such an important factor in the transmission of power by gears that an attempt was made to measure it and determine how it is influenced by the lubricant used. After consulting several authorities, the following apparatus was suggested by the Western Electric Co., which was also kind enough to lend it. A microphone

[3] See *Mechanical Engineering*, November, 1920, p. 613.
[4] See *Journal of the American Institute of Electrical Engineers*, September, 1921, p. 724.
[5] See *Transactions of the American Society of Mechanical Engineers*, vol. 37, p. 520.
[6] See *Automotive Industries*, Nov. 3, 1921, p. 865.

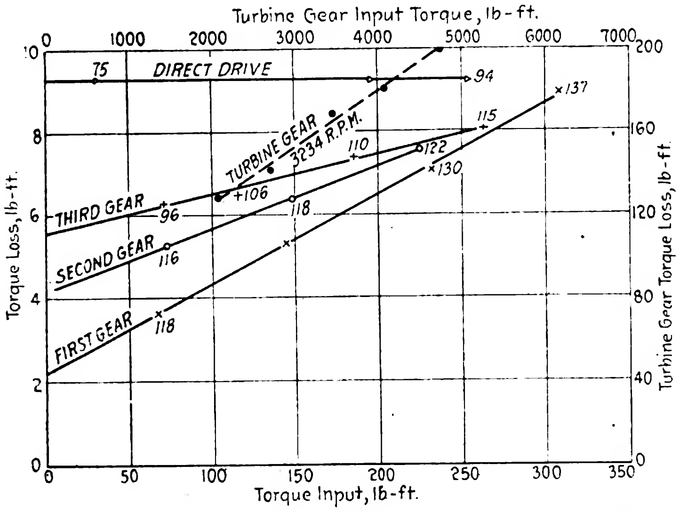


FIG. 13—RELATION BETWEEN THE TORQUE INPUT AND LOSS IS A MINIMUM ON THE FIRST GEAR AND A MAXIMUM ON THE DIRECT DRIVE

The Figures Given on the Curves Are the Oil Temperatures

of the inertia type, without a diaphragm, was connected in series with a single cell of storage battery and the heating coil of a thermocouple, the thermocouple itself being connected directly to a direct-current microammeter. With the microphone button in contact with the outside of the gearcase, the microammeter pointer gave a reading that was recorded as a measure of the energy of vibration of the case, and was assumed to be a measure of the noise produced by this vibration. As slightly dif-

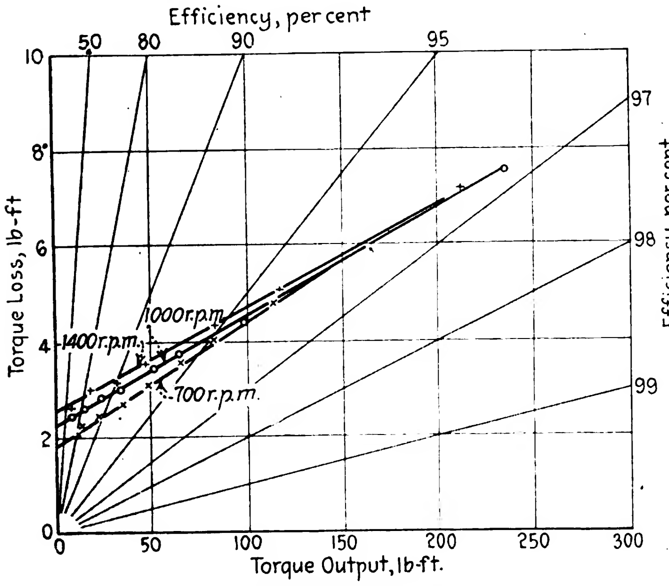


FIG. 14—LOSSES WHEN TRANSMITTING POWER AT VARIOUS SPEEDS

ferent readings resulted from contact with different parts of the case, contact was made at approximately the same point, at a corner, for all subsequent readings. Fig. 16 shows the results on direct drive and also on second gear. The pronounced crest of these curves, when one would expect them to continue upward, indicates that the microphone was not adapted to periods of vibration as high as those experienced. A change in the microphone was made but this was not much of an improvement. It is clear that further development will be necessary to make this apparatus useful, and there is little doubt that this can be done.

It has been shown that friction losses in a gearset consist of two distinct types; (*a*) those existing while idling or transmitting no power and (*b*) additional losses while transmitting power. The former were shown to be the sum of a constant and a factor for the fluid friction that varies with the viscosity and quantity of oil as well as with the number of revolutions per minute of the gears. When it is desirable, these factors can be formulated for a gearset so that the losses can be calculated with reasonable precision for all combinations of the variables involved. It has been shown also that an appreciable increase in efficiency will result by lowering the viscosity of the oil, particularly when the gearset is used for direct drive on a level road. Recommendations to use oils of low viscosity cannot yet be made, however, because of insufficient knowledge of the rate of wear and

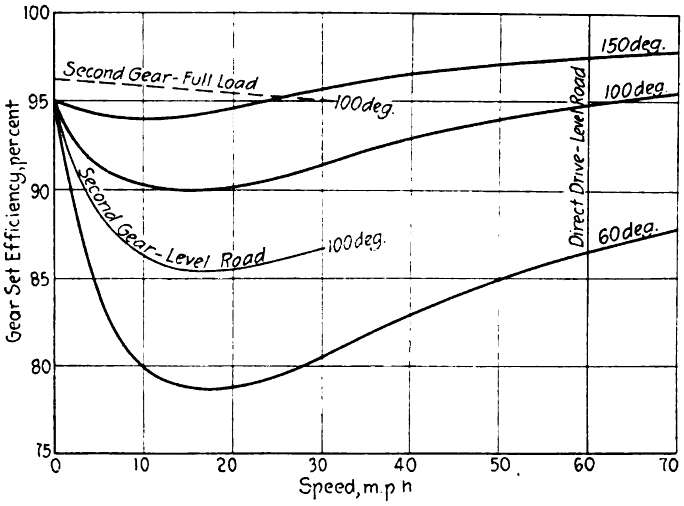


FIG. 15—THE EFFICIENCY OF THE GEARSET AT VARIOUS GEAR SPEEDS

The Figures at the Ends of the Curves Indicate the Oil Temperatures

volume of noise resulting from their use. It is doubtful if there will be any noticeable increase in the wear of an automobile gearset if an oil similar to a heavy motor oil be used, particularly since these gears are not used continually. The De Dion-Bouton trucks have made a very successful use of such an oil for their gearsets.

The data that have been given here are very suggestive for further analytical study, in regard to both gearsets and other parts of the power system of a motor vehicle. Time thus taken promises well to increase the efficiency of motor-vehicle transportation and reduce its cost, as well as to make our fuel resources last longer.

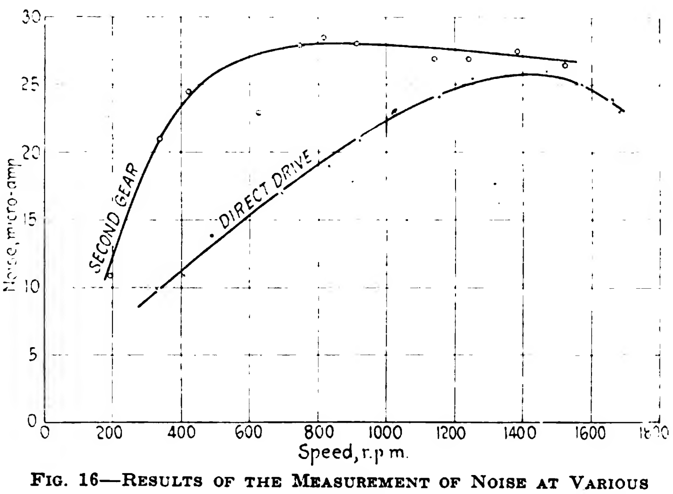


FIG. 16—RESULTS OF THE MEASUREMENT OF NOISE AT VARIOUS SPEEDS

The Past, Present and Future of the Motor-Omnibus

By WALTER JACKSON [1]

ANNUAL MEETING PAPER

AFTER outlining motor-bus history and relating how the introduction of mechanical and electrical propulsion on rails relegated horse-buses to the background, the author states that electric-railway construction is at a standstill and that the present demand for additional transportation facilities is being met by motor-buses that often are operated by individuals; presents railway statistics and comparative comment on jitneys, cross-country motor-buses and supplementary motor-bus service by electric-railway companies; and mentions many influential factors concerning motor-bus utilization.

Future motor-bus considerations include discussions of fare rates and operating expenses. The author believes that a comparison of the true cost of electric-railway versus motor-bus service has been obscured by certain factors having nothing to do with the engineering aspects of the situation, and that the economic fields of these services will be determined by the co-ordination of all mass transportation under one management instead of permitting indiscriminate and destructive competition.

THE writer on steam turbines seldom fails to refer to the time of the late Hero of Alexandria, a trifle more than 2000 years ago, and one who presents a paper on the road transportation of passengers must face the temptation of dragging forth the ghosts of Egyptian sledges, Roman chariots and English stage-coaches; but I will put the pleasing provocation by and plunge at once into a period no further back than that of our great-grandfathers. In the decade of 1830-1840 some serious and creditable efforts were made to produce a trackless, self-propelled vehicle. Indeed, as early as 1828 Sir Goldworthy Gurney's steam coach was making the 9 miles between Gloucester and Cheltenham in 45 to 55 min. Three years later the Ogle-Summers steam carriage was fleeting along the highways at 30 to 35 m.p.h., utilizing a modern boiler-pressure of 250 lb. per sq. in. Inventor after inventor came into the field within the next few years but, through the influence of the railroads, there was placed upon the statutes the absurd provision that each and every steam engine operated over the public highways should be preceded by a man carrying a red flag, at a walk, of course. The rate of locomotion, ironically termed "speed," was limited to 4 m.p.h., and railroad shareholders and horses were saved from fainting fits by permitting such vehicles to run only in the darkling hours of 10 p.m. to 6 a.m. College debating clubs may still argue whether legislation really can block the bus of progress very long, but here is a record of legislative obstruction that proved effective for more than two generations.

The net result was that, both here and in England, the field of passenger transport was left to the steam railroad and the horse-drawn omnibus. The latter was first succeeded by horse-drawn railway cars, for those were decidedly not the days of smooth paving, and then by the cable and the electric railways. For a time, it seemed that the electric railway would become the sole means of public-utility transport in city and suburban areas but, after two frenzied decades of expansion, it was seen that while electric traction is technically right there are plenty of places where it is financially wrong.

It would not be fair to criticize the old-timers too severely for the construction of uneconomic lines. They knew no other form of mechanical propulsion that would relieve them of the great cost of power-stations, substations, distribution systems and other rooted structures that go with the humblest electric railway. When electric-railway building was at its peak, the gasoline vehicle was in its first stages. The electric-traction men were not in the same position as the horse-drawn-omnibus operators of London who had to seek something faster and better without recourse to the rail. They refused to indulge in watchful waiting, but blithely went on to build thousands of miles of track through districts that did not produce enough business to meet operating expenses alone.

THE PRESENT

There was 47,941 miles of electric single trackage in the United States in 1919. In 1920 the mileage showed a decrease for the first time in the history of the industry, being 47,705 miles or a loss of 236 miles. The figures for 1921 may show a still greater loss. These declines are due to the deliberate abandonment of non-paying lines, principally of systems in receivership that are not compelled to continue to observe original franchise stipulations.

In cities so large as Bridgeport, Conn., and Des Moines, Iowa, we have seen extended periods of idleness on the part of the local traction systems. In the one case it was the hope of the traction company to compel the absolute elimination of jitney competition; in the other there was a desperate effort to secure a higher rate of fare. Like scenes are being enacted in other cities. One would not expect sane communities to prefer to exchange even a fairly reliable street railway under one corporate management for the uncertain, hard-to-please but far from coy jitney man. Yet they have shown themselves willing to put up with atrocious jitney operation for weeks and months rather than submit to the demands of the street railway. In short, the lack of good-will toward the electric railway blinds the community to settling its transportation problem upon the commonsense basis of all mass transportation in a community, regardless of the manner of propulsion, being under a central, coordinated management. So far, some electric-railway companies have not seen their opportunity to absorb unto themselves whatever special advantages the bus has for attracting traffic and reducing the operating costs of certain classes of service. They have actually given the impression by their antagonistic attitude that the field of the motor-omnibus is greater than it really is on the basis of present-day development, and they are encouraging the fol-

[1] Consulting engineer, Mt. Vernon, N. Y.

mation of motor-bus companies whose promoters seem very much in the dark as to the requirements of an exacting public.

It is significant that, while no important city has given up its railway system to change to the jitney-bus, the substitution of motor-buses for the cross-country trolley-car seems to be meeting with public favor. This class of trolley line usually has a single track, which handicaps its schedules; and, as most of its former patrons own motor-cars, the clientele tends to decrease year by year. Besides, the very advent of improved roads is a bane to this class of trolley in another direction, namely, that of re-alignment to new paving levels. Few such railways can afford to get out of the dirt and into the paving; so, they quit. The abandonment of several hundred miles of track by the Eastern Massachusetts Street Railway Co. alone is a forerunner of what other railways with cross-country lines on public highways are facing.

The development of both electric and steam railways in this Country has been on such a grandiose scale that one would hardly expect to find any community of considerable size without transportation service. Nevertheless, there has been already an imposing development of motor-bus transportation in non-competitive districts. Out of a city like Poughkeepsie, N. Y., for example, a number of individually owned motor-bus enterprises are operated which tap territory without railway service of any kind. There are literally thousands of one-man services of this kind that are performing a most valuable function. They produce a living for men who are willing to work 12 to 16 hr. per day, but would not do for companies from whom the community would demand better vehicles and more frequent service. There must be some deep-rooted belief that individuals in the public-transportation field are deserving fellows entitled to get away with anything; whereas, company organization at once implies that there are great profits for somebody somewhere, this implication meaning higher standards and higher taxes.

Jitney Competition

So far as jitney operation is concerned, that is here today, gone tomorrow and back again day after tomorrow. Endless State and municipal measures have been passed at the behest of both the railways and the public and, I may add, even at the behest of jitney men who have achieved the status of a vested interest and want protection against later comers. But much of this legislation seems to fall to the ground whenever the local street-railway company and the administration disagree. One day sees all the second-hand cars in town soliciting patronage, usually at a lower fare. The news travels and a hegira sets in toward the new jitney Medin. Thus, in the recent Des Moines trouble jitneys thrown out of Connecticut actually were driven overland to Iowa to obtain their share of the abnormal patronage.

Overland Motor-Buses

It has been more difficult to regulate the competitive overland motor-bus than the city jitney. The exclusive franchises that electric railways lean upon in municipalities do not apply to the country, where the electric railway may be a blend of city, highway and right-of-way operation. Often enough, the buses do not parallel the railway all the way but only in part. If they reach, in addition, off-side districts not served by the railway, it is hard for a State commission to say whether the proposed bus-route is entitled to a certificate of convenience and necessity. Most of the overland-bus companies, those in California and Washington, for example, charge lower fares than the railways, but the chief reason for their getting the business seems to be that they come closer to the patrons' origin and destination than the railways. In California, particularly, the delights of the climate are a strong temptation to outdoor riding.

As already hinted, the only curb on these cross-country or overland-bus operators is that they must in a growing number of States like Connecticut, New York, Pennsylvania, Illinois, New Jersey, California and Washington obtain certificates of convenience and necessity. This curb is of varying degrees of value, dependent upon the viewpoint of the commission. In one case the Illinois commission granted a certificate permitting competition against an electric railway because the latter had not met the commission's ideas of a proper standard of service; but the same commission refused a certificate to another applicant who wanted to compete with an electric railway giving satisfactory service. Commissions are inclined to give certificates in cases where a large part of the run will not be in competitive territory; and in competitive territory they may grant operating rights because of the lower fare offered.

Motor-Bus Legislation

The latest motor-bus legislation in which both city and country operation are placed under the State commission is that of Connecticut and of New Jersey. In the latter State, however, the commission exercises no control over operators who had regular routes before the time of the passage of the act, March 15, 1921. The question now before the courts is whether this exception constitutes a vested or property right that can be transferred to a successor. In the first case brought up the Board of Public Utility Commissioners granted this succession right to one Carl A. Becker, but the Public Service Railway Co. within whose area Becker operates has appealed the case. The point made by the commissioners was that the bus operators active at the time of the act had been regulated already as to number and routes by the local municipalities, and that they were therefore, presumably, fulfilling a work of convenience and necessity. Under their conception of the law entirely new petitioners can apply to them for routes, provided they have obtained approval previously from the local governments.

The cities of Connecticut never undertook to license public-utility vehicles; so the new legislation did not deprive them of any powers theretofore exercised. All that a jitney operator needed was the nominal State license for a public-utility vehicle, and all the regulation he endured was what the police chose to exact, as was evident particularly at Bridgeport. Theoretically, the Connecticut Public Utilities Commission is not obliged to pay much attention to what the different cities may desire, but practically it is under this obligation. In the city of Hartford, for example, the elimination of the jitney met with general approval. Contrariwise, the large working population of Bridgeport was bitterly opposed to paying a 10-cent fare on the cars in view of the fact that it had thitherto had a 5-cent fare on the jitney-buses. Preceding the passage of the State law, the Bridgeport council had agreed to relegate the buses to streets on which there were no car tracks, so far as that was physically possible. Despite this handicap the buses continued to get most of the traffic. When the State commission endeavored to put these jitneys out of business the latter adopted one subterfuge after another, such as accepting tickets from alleged club-members, besides securing stays from the courts. The commission itself, recognizing the hardship of a 10-cent fare, has ordered

lately a 5-cent short-ride fare and threatened to grant additional bus licenses if the electric railway does not give satisfactory rates and service.

I have gone into these nearby situations at some length to indicate that, while the regulatory bodies are gradually assuming control of motor-bus operation, it does not follow that the electric railways can afford to show indifference to the public. The people will find some way of getting what they want, sooner or later. It seems incredible that the electric railways themselves have been among the opponents of legislation that would grant the common carrier under discussion the right to run motor-buses. They actually feared that such recognition of the transportation usefulness of the motor-bus would make all of their own precious investments passé. This was topsy-turvy reasoning. The bus did not need this legislation to prove what it can do. Thus far not more than a score or so of our 800 to 900 operating railway companies have undertaken motor-bus operation, but even these few pioneers give a clue to some of the valuable results that can be attained with the motor-bus. One large city railway company has installed buses over a poorly traveled route to save the expense of retracking and repaving; another has given up a dangerous run along a steep river-bank to follow a shorter line on the highway; a third has cut down the losses on a roundabout electric railway by offering a shorter faster alternative bus route; a fourth has found that a bus-line makes it unnecessary to disturb a cherished public park; a fifth finds the bus the least costly medium for tieing together two important rail-routes; a sixth has made one loop out of two former trackways; and several others have found the bus a most desirable vehicle to ward off the cost of track extensions until new business justifies the old burdens.

We are all familiar with the splendid organization of the Fifth Avenue Coach Co., New York City, that combines both technical and sales leadership in its work. But this company, like the other double-deck bus operators in Detroit and Chicago, is doing a work somewhat apart from the usual organization that is responsible for all the mass transportation of the community.

Summarizing the present situation as to the motor-bus, we have the unreliable competitive jitney; the rapidly growing cross-country bus, sometimes competitive and sometimes creative; the beginnings of motor-bus operation by electric railways; the de luxe double-decker; and, finally, the "on call" motor-buses and char-a-bancs that may some day achieve the same widespread popularity they have attained in England.

The Future

Will the city and suburban electric-railway disappear altogether and the steam railroad be discontinued in part; or, will the increase in motor-buses be due more to the creation of new business because of their unlimited flexibility? The general public, unfamiliar with the cost of either mode of propulsion, cannot be blamed for thinking that the trolley-car is doomed when it observes the jitney charging half the fare and making 50 per cent greater speed; but the automotive engineer can be blamed if he fails to see that these two forms of transportation are not compared so easily as that.

The electric railway of today is the product of two generations of corporate life. During those generations it has accumulated a number of unwholesome factors that place it at a disadvantage in competition, entirely aside from the question of engineering merit. There is, for example, the fundamental franchise obligation that a certain amount of service must be given regardless of traffic, an obligation from which the jitney is almost or entirely free. There is the paving obligation from which the very jitney that runs over that paving is free. There is that host of taxes on costly buildings and land, on income, on the corporate form, sometimes even on trolley-poles or cars, from which the jitney suffers next to nothing. There is the curse of the same fare regardless of the length of the ride, while the jitney travels no farther than the fare will cover.

These are some of the burdens for which the railways themselves are not responsible to any degree, and they are burdens that would be paralleled in the long run by any regularly organized motor-bus company. The Fifth Avenue Coach Co. is not only the oldest and largest motor-bus organization in the United States, but it is the one that has gathered unto itself the largest tax-bill in proportion to earnings. And the gallonage tax is yet to come! Since these are burdens imposed by the State, they will become equalized in time; so they present no really great danger for the older utility. In truth, the burdens that the electric railway has accumulated without the help of government are far greater. If these are not shaken off or greatly reduced in weight, the motor-bus in independent well-monied hands will prove a real danger and supplanter in many of the smaller and medium-sized communities. First of all, the failure in the past to set aside amortization and depreciation funds to care for advances in the art has led to excessive replacement-needs at this time. Many companies are compelled to continue to operate with obsolete equipment because they cannot borrow the money for efficient apparatus, thus suffering much higher operating costs than the actual state of the art makes possible.

Rates of Fare

In the second place, in seeking a rate of fare that will restore their credit, electric railways have valued their property on a "reproduction-cost-new" basis and then sought also a war-time rate of return on this valuation. The consequence, in a number of cases, has been that the resultant fare required is so high as to frighten off an appreciable proportion of the traffic. This brings us to the vital question, Have electric-railway fares reached a point where the motor-bus can compete against and supplant the electric railway? I say without hesitation that any small-city electric-railway charging a 10-cent fare today is absolutely vulnerable to such competition, should the State allow a capably organized company to come in. There are some two score communities of that character charging a flat fare of 10 cents, and between 40 and 50 cities or towns charging a 10-cent cash fare and 6 to 9 cents for a ticket.

The railways in 70 to 80 communities charging 8 and 9-cent fares are also in danger, provided the length of route is within 3.0 to 3.5 miles. The 7-cent and 6-cent street-railways hardly could be touched by a motor-bus company so long as both had the same scheme of charging one fare regardless of the length of ride; but, if the motor-bus operators were wise enough to do business only on a distance-fare basis from the start, they would be able to begin at a 5-cent minimum for say 1 mile. Therefore, it will be seen that unless the electric railways in such districts are willing to write down their valuations as remorselessly as a merchant writes down his outof-date stock, they will not be saved by their inherently lower operating expenses. Here I may be taken up short by the over-enthusiastic bus-advocate who does not like

that last phrase about "inherently lower operating expenses." Nevertheless, it is true.

Motor-Bus Expense

It has been my work to analyze a great variety of motor-bus expenses, both real and theoretical. The real set-ups of actual expenses have been chiefly in Great Britain, where the motor-bus is a valuable and important part of the mass-transportation system and is almost always in railway hands. Although the basic costs differ materially from ours in at least the item of fuel, we know that they are based on actual and not theoretical conditions. When we look for the corresponding items in cost set-ups in this Country we find, with few exceptions, that a considerable number of items have been overlooked. For example, many of the estimates show a cost of 1 cent per seat-mile, whereas inclusion of all legitimate items in company operation would bring the cost to 1.5 and even 2.0 cents per seat-mile. The accounts of electric railways operating motor-buses confirm this estimate. Double-deck buses would be somewhat cheaper, of course, on the seat-mile basis. On the basis of the few well-kept accounts available in the United States it would seem that a 10-cent fare is the right fare for high-grade motor-bus service covering rides in excess of 3 or 4 miles average length. Only one-man operation in congested streets and within a route length of 2 miles offers the opportunity for anything like a 5-cent fare.

The statements of the average jitney operator are poor guides to the correct cost estimate of a genuine motor-bus service. The jitneur works many more hours per day for himself than he would work for others, in running the car and in taking care of it. He has a direct incentive to collect all the fares and to waste no materials. He is just as liable as not to store his bus in the open. As for a standard of cleanliness, heating and maintenance, it does not exist and therefore costs nothing to get. The statements of builders are necessarily more general. It is right for them to expect a certain number of miles per gallon of gasoline and lubricant and to anticipate a certain maintenance cost and depreciation per mile on the assumption that the operator will be careful and that he is equipped with proper facilities. It is not right for the prospective purchaser to accept these estimates unless he knows he can fulfil the builders' expectations in those two respects.

Daily mileage is an important element in determining costs. There is a wide difference between the cross country vehicle that will make a practically non-stop run over a perfect highway with a good load between its terminals and the vehicle that will be used in any of the many varieties of city service. It makes a difference whether one runs 200 or 100 miles per day. The bus may be perfectly capable of doing 200 miles, but will there be any necessity for it in the given situation? As previously indicated, a number of uses for the motor-bus lie in the operation of extensions or crosstown services where traffic is thin and it is cheaper to have long lie-overs than to keep the vehicle shuttling back and forth. As a matter of fact, the operating cost of a modern safety one-man car is little more than half as much as the operating cost of a motor-bus of equal capacity. When we come to larger units, such as two-car and three-car surface trains, the disparity is just as great, aside from the fact that the same capacity in buses of single-deck type, in any case, would not be available in the same area. The superiority of the best motor-bus to the best street-car does not lie in any saving in operating or running costs. It lies in the ability to meet situations, some of which already have been described, that no track-bound vehicle of any type could solve. We cannot expect the bus to replace the car on a large scale except where the electric railway deliberately commits suicide. We can expect it to do what it already has done in Great Britain, to put a stop to all trackage development except extensions that will have heavy travel from the very first day that such routes are completely opened for the regular transportation of passengers.

The great sums that have been put into electric railways are not to be wiped out forthwith, although they are to be cut by the lopping off of weaker lines and small systems. But the future does belong almost entirely to the motor-bus because it makes possible the investment of capital in direct proportion to the business available instead of demanding almost as much investment for 50,000 as for 500,000 car-miles per annum. It is not necessary to assume the complete supersession of the electric city-railway as a necessity for large motor-bus development. The appetite of the people for transportation is far from satiated. What we should strive for is to secure constructive coordination rather than destructive competition, realizing that mass transportation is inherently a monopoly and should be under one direction whether the vehicles are propelled on a track or on tires, by electricity or by internal combustion. Only in that way will each form of transportation find its true economic place.

INTERNAL-COMBUSTION ENGINE FUELS

(*Concluded from page* 192)

prime requisite, in the case of which the relative merits of wet and dry mixtures are still debatable.

Professor Norman:—In that connection I would like to have the power of the tractor determined after it has been plowing several months. With a wet mixture including raw fuel entering the tractor-engine cylinders on starting, it passes the pistons, dilutes the crankcase oil and becomes mixed with some of the dust of the field in the cylinders. At the end of a season's plowing, on account of the leakage and friction, the condition is worse in point of power than it would be if the dry mixture had been used all the time.

Recent Aircraft Engine Developments

By C. FAYETTE TAYLOR[1]

DAYTON SECTION PAPER *Illustrated with* PHOTOGRAPHS

AFTER indicating the line of development since November, 1918, toward making the internal-combustion engine better adapted to aircraft service, the successful application of the supercharger to improve engine performance at great altitude is described and the over-dimensioned and over-compressed engine also is discussed as a means toward that end.

The use of anti-knock compounds to permit the use of high compression-ratios at small altitudes without knocking is commented upon and engine size is considered for both airplane and dirigible service. Further review includes air-cooling experiments in reference to the air-cooled radial engine, refinement of aviation-engine details, and improvements in aircraft powerplant parts and fuel-supply systems. For commercial aviation, powerplant reliability and low cost are stated as essentials. Illustrations are presented of the supercharger and of the engines and sylphon fuel-pump mentioned.

THE purpose of this paper is to outline briefly the most important advances in aircraft engines that have taken place since the armistice was signed on Nov. 11, 1918. These developments have been along the lines of improving engine performance at altitude, increasing power and efficiency through use of high compression and "doped" fuel, development of large engine units, experimentation in air-cooling, and refinement of detail, with a view to making the internal-combustion engine better adapted to aircraft service.

Perhaps the most notable of these developments is the successful application of the supercharger to improve engine performance at great altitudes. The desirability of supercharging was realized late in the war and several experimental superchargers were built and tested, but it was not until about six months after the armistice that the first successful flight while using a supercharger was made in this country. The supercharger used was designed by Dr. S. A. Moss of the General Electric Company, and was installed and flown at McCook Field by the engineering division of the Army Air Service. Fig. 1 is a photograph of the present type of General Electric supercharger mounted on a 12-cylinder Liberty engine. This supercharger is a development of the one that was first flown in the spring of 1919 and has been in successful use since that time. It is of the centrifugal compressor type, driven by a single-stage exhaust-driven turbine. The single rotating unit consists of a forged-steel compressor-rotor that is located in an aluminum housing at the front of the engine and on the same shaft with the turbine, which is immediately behind the engine. The compressor outlet discharges into the intercooler and thence to the carbureters. The intercooler is a new development and consists of a bank of exposed tubes to reduce the temperature of the air after it has passed through the blower and become heated by compression and friction. The speed of the turbine blower-unit, and hence the supercharging pressure, are controlled by the exhaust gates or bypass valves at the rear of the exhaust-manifolds, which govern the amount of exhaust gases going to the turbine. The normal speed of the rotating element is 20,000 r.p.m. The supercharger unit, as shown in Fig. 1, can be said to be a successful development in itself. However, the problems of fuel supply to the carbureters and of proper carburetion under supercharging conditions are not solved in a satisfactory manner, and much work remains to be done along this line. The cooling of the supercharged engine and the necessary variable-pitch propeller are special problems that already have been worked out in a fairly satisfactory manner.

THE OVER-DIMENSIONED AND OVER-COMPRESSED ENGINE

Another method of improving engine performance at altitude that has received much attention since the armistice is the over-dimensioned and over-compressed engine that has been developed from the normal type by increasing the cylinder bore and compression-ratio without increasing the size of the crankshaft, crankcase, connecting-rods or other important parts. At small altitudes, the oversize engine, as it is called, is held down to the maximum power output of the original normal engine by throttling but, above a certain height determined by the design, it can be run wide-open and advantage taken of the increased performance because of the larger displacement and increased compression-ratio. Due to the decreased air-density, the oversize engine is subjected to no higher cylinder pressures when run wide-open at or above its design altitude than the normal engine is when run wide-open at sea level. A remarkable feature of the over-compressed engine is the great fuel economy made possible by the high compression. Even when throttled to the maximum allowable power output at sea level, brake thermal efficiencies of over 28 per cent are obtained readily and it is probable that slightly higher efficiencies are obtained under favorable circumstances at the smallest altitude at which the engine can be run wide-open. Notable examples of over-dimensioned and over-compressed engines are the B.M.W. engine which was put into service by the Germans just before the armistice, and the Packard 12-cylinder engine, shown in Fig. 2, which is a joint development of the Packard Motor Car Co. and the engineering division of the Air Service. The Liberty engine also has been successfully modified to incorporate the over-compression feature and thus improve its performance at great altitude.

ANTI-KNOCK COMPOUNDS

Coupled closely with the development of the over-compressed engine is the adoption of special anti-knock compounds to be mixed with gasoline to allow the use of high compression-ratios at small altitudes without knocking or detonation. The work done by Thomas Midgley, Jr., of the General Motors Research Corporation, has been applied to aviation engines with distinct success. This is particularly useful in military work where the maximum possible power output of a given engine may be demanded at small altitudes, for special types of service. By using comparatively small quantities of these anti-knock com-

[1]Jun. S.A.E.—Engineer in charge of powerplant laboratory, engineering division, Air Service, McCook Field, Dayton, Ohio.

pounds, it has been possible to raise the compression-ratio of the Liberty engine sufficiently to increase the sea-level power-output 12 per cent without increasing the amount of fuel consumed. By sacrificing only a part of this gain in power and still using the anti-knock compound, the increased compression-ratio allows extremely lean fuel-mixtures to be burned with remarkable results in respect to fuel economy. Under such conditions the fuel consumption of the Liberty engine can be brought down to 0.44 lb. per b. hp-hr. in actual flight, or a brake thermal efficiency of nearly 30 per cent, which is considerably better than that of the average Diesel engine.

A notable instance of the possibility of obtaining high power-output by raising the compression-ratio and using an anti-knock compound is the case of a 5 x 7-in. cylinder used by the engineering division of the Air Service for test work. This cylinder repeatedly has given over 42 b. hp. at 1700 r.p.m., which corresponds to a brake mean effective pressure of 142 lb. per sq. in. and an indicated mean effective pressure of 177 lb. per sq. in. If the Ford engine could be made to give the same power-output in proportion to its displacement, 54 hp. would be developed instead of the normal output of 18 hp. A significant phase of the use of anti-knock compounds and high compression-ratios is that the maximum pressures that occur in the cylinder, and hence the maximum stresses in the engine, are not increased greatly. A considerable amount of detonation is present in aviation engines of normal compression-ratio using standard aviation fuel and, when this detonation is eliminated by an anti-knock compound, the compression-ratio can be increased considerably without reaching cylinder pressures as high as those of detonation under the normal conditions. By using a small percentage of such a compound in the fuel with engines of normal compression-ratio, it is expected that the life of the engine and its reliability can be increased considerably.

Fig. 1—The Moss Supercharger Mounted on a 12-Cylinder Liberty Engine

Fig. 2—A 12-Cylinder Engine That Was Developed Jointly by the Packard Motor Car Co. and the Engineering Division of the Air Service

Aircraft-Engine Size and Cooling

In regard to engine size, the advent of aviation engines of over 500 hp. has been a distinct development since the armistice. The only successful engine of over 500 hp. to be flown before the armistice was the Italian 12-cylinder F.I.A.T., that was rated at 650 hp. This is a very heavy engine for its power, and just how successful it has been is open to question. Since the armistice there have been designed and built in England four types of engine of 500 hp. or over, one of which, the Napier Cub, has been reported recently to have developed over 1000 b. hp. on test. Approximately 12 engines of 500 hp. or over have been designed in France, but just how many of them have been actually built and tested is not known. So far as can be learned, none of the large British or French engines has yet passed the experimental stage. This country has produced the 500-hp. Packard engine shown in Fig. 3 and the engineering division of the Air Service the 700-hp. Model-W engine illustrated in Fig. 4, both of which bid fair to be successful types. Plans are being laid in this Country for even larger engines and the limit in the size and number of cylinders has not yet been reached. It is believed that the large engines, making

Fig. 3—The 550-Hp. Engine Produced by the Packard Motor Car Co.

possible very large airplanes, may lead to unforeseen developments in commercial as well as military aeronautics.

The situation in this Country in regard to engines for lighter-than-air service has improved to some extent since the armistice. At that time there was only one small American engine designed especially for dirigible use. At present at least two American firms are building 350-hp. engines that incorporate all of the most uptodate requirements of this service. This development is being carried on under the direction of the Bureau of Engineering of the Navy Department.

Appreciating the important advantages of the air-cooled radial engine for certain classes of service, the engineering division of the Air Service has conducted experiments on air-cooling on an extensive scale. Due to the extraordinary difficulties in air-cooling cylinders of sufficiently large size for military engines, this work has proceeded slowly and no engines of this type have yet emerged from the experimental stage. Considerable progress has been made, however, and it can be predicted confidently that a successful air-cooled engine of over 300 hp. will be forthcoming within the present year. In connection with the subject of air-cooling considerable credit is due the Lawrence Aero Engine Corporation for having developed a small air-cooled aviation engine the performance of which equals that of the average water-cooled aviation engine in proportion to its displacement.

Aircraft Powerplant Refinement

In addition to the specific developments already described, there has been remarkable refinement of detail in aviation engines. From the viewpoints of maintenance, installation, and accessibility of those parts requiring frequent attention in particular, much progress has been made. Figs. 2 and 3 show in part how this has been accomplished. The absence of accessories on the anti-propeller end of the engine, which usually abuts a fire-wall in an airplane installation, is particularly noticeable. The carbureters are located below the crankcase both for accessibility and to allow the use of gravity fuel-feed. The water pump, oil-screen, ignition apparatus and spark-plugs, where possible, are all located so as to be accessible from the sides. The importance of such details in aviation work cannot be overestimated, because so much depends upon keeping the engine accessories in good condition.

Parts of the aircraft powerplant outside of the engine have been undergoing steady development. This is especially the case with the cooling system. Relieved from the pressure of war work, the various research laboratories have had time to determine carefully the most efficient and practical types of radiator core. The best modern cores are built up of thin copper tubes approximately 1/4 in. in diameter; and these are expanded to hexagonal shape at either end, where they are soldered together. The length of the tubes varies from 4 to 9 in., depending upon the air velocity through the core. This type of core lends itself readily to quantity production and has a relatively high efficiency.

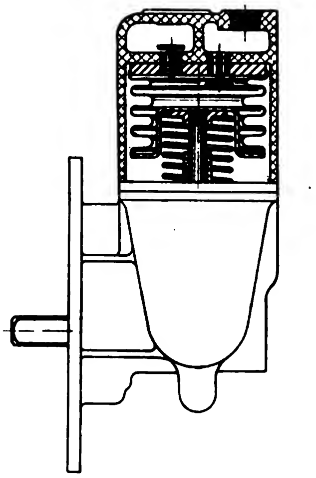


Fig. 5—The Sylphon Pump for the Fuel-Supply System of an Airplane That Was Designed by the Air Service

New developments in the fuel-supply system include the abandonment of the air-pressure method for military use, due to its vulnerability. Instead, fuel-pumps driven by the engine are becoming almost universal, although wind-driven pumps are still popular. The sylphon pump designed by the Air Service and shown in Fig. 5 is a very successful engine-driven pump of which the operating member consists of a pair of cylindrical metal bellows operated by cams, with a spring return to limit the maximum pressure without the use of relief valves. For military service an auxiliary system is invariably supplied, which is either gravity or hand-operated. Commercial powerplants usually employ the air-pressure system because of its simplicity and reliability.

One thing that does not appear to have been developed in this Country is an engine entirely suitable for commercial aviation. Here powerplant reliability becomes a very important factor, since the safety of the passengers or the goods carried depends upon the continuous operation of the engine. This aspect of the situation has been obscured somewhat in military aeronautics, where many other factors are thought to be of nearly equal importance. It is believed that the greatest single step toward successful commercial aviation would be the development of a powerplant as reliable as that of the marine steam-engine. The problem of reliability is as much one of the smaller parts of the powerplant, such as the fuel-supply and the ignition systems and spark-plugs, as it is of the engine itself, and in making these parts more dependable lies an important field for future development.

Another extremely important requirement of the commercial engine is low cost. Here, again, the military designs, in which cost is a minor consideration, have exerted a retarding influence. Present-day airplane engines are enormously expensive in both initial cost and maintenance and until this phase of the situation shall have been overcome the development of the commercial airplane engine will be very slow.

Fig. 4—The 700-Hp. Model W Engine Developed by the Air Service

Drop-Forging Practice

By J. H. Nelson[1]

Annual Meeting Paper

THE author discusses drop-forging practice from the standpoint of the materials used, and strongly advocates a more rigid inspection and testing of raw products to determine their fitness for use in making automatic forgings.

Seven specific possibilities of actual difference between drop-forgings that are apparently identical are stated, the requirements of the inspection of raw stock are commented upon, and the heat-treatment and testing of finished forgings are considered at some length.

Tabular data of the chemical analyses and physical properties of 107 different heats of carbon-steel used recently are presented and show a variation in drawing temperatures of 140 deg. fahr. in steels of practically the same chemical composition to meet the same physical-property specification, based on more than 1000 tests on this grade of steel taken from production stock. The concluding summary has five specific divisions.

SOME very rapid and stupendous developments have occurred in a large number of industries within the past decade. Chief among these is the automotive industry, which has forged forward from a comparatively inconspicuous beginning to become one of the largest and most highly specialized industries of today. One of the principal reasons for this rapid development is the willingness and eagerness with which those in responsible charge seized upon and completely assimilated new ideas and methods that make for better and more rapid production. Many industries have contributed toward this development either directly or indirectly. It is impossible to measure with any degree of accuracy the exact value of each of their contributions. The drop-forging industry, which itself is comparatively young, has contributed in a large measure to this phenomenal advance by successfully forging from steels of various compositions some of the most vital parts that enter into the construction of automotive vehicles. In the early history of the automotive industry, when quantity requirements were small, the cost of drop-forgings was prohibitive to a large extent. The result was that the manufacturer was compelled to resort to castings or hand-forgings to supply his needs. As his requirements increased and designs became more stabilized, he was able to purchase drop-forgings of far superior quality to compete in price with castings and hand-forgings.

Drop-forgings for automotive construction are made today in large quantities from a great variety of steels, both plain-carbon and alloy, the particular grade of steel used being dependent upon the part to be forged and the duty required of the part. With the increase in the number of forge-shops that has occurred within the last few years, it is no longer a problem to have a forging made, but rather to secure the necessary quality in the forging when completed; and this matter of satisfactory quality is not something that is apparent on the surface of the forging. Two forgings may be identical in appearance, size, shape, amount of finish and even forged from the same grade of material; yet, from a quality standpoint, they may be decidedly different. This difference may be due to any one or to a combination of the following factors

(1) Method of forging
(2) Method of heating for forging
(3) Inspection and supervision of forging
(4) Inspection of raw stock
(5) Segregation of raw stock
(6) Heat-treatment of the finished forging
(7) Testing of the finished product

It is not the intention to discuss the effects of all of these factors on a finished forging, but rather to confine the discussion to the last four, these having to do with the materials entering into the forging and with its subsequent treatment.

Inspection of Raw Stock

Inspection of raw stock should consist of (*a*) surface inspection to determine the fitness of the material for use in forgings, such as an examination for size, seams, scale, burns and the like, and (*b*) chemical analysis to determine the fitness for use in the various parts, to determine the segregation of the elements in the bars and to determine mixed heats.

Mixed heats are of two kinds, those that are deliberately mixed at the mill and those that are accidentally mixed at the mill. Under deliberately mixed heats, we find steels of the same grade but from different melts that are rolled into bars and furnished to a customer under the same heat number. Such heats are made up from ingots that have the same or nearly the same chemical composition as to the hardening or alloying constituents. Heats of this character are an endless source of trouble to forge-shops that endeavor to keep melts of steel of the same grade segregated. Unintentionally mixed heats are due to a few bars of a different grade of steel becoming misplaced. While this is a source of annoyance, it is readily detected chemically and the bars are then rejected.

Segregation of Raw Stock

Segregation of raw stock of the same grade by melts is absolutely essential if quality forgings are to be produced. Many shops and plants fail to recognize this fact and segregate their stock by size and grade only. It not only is necessary to segregate the stock in the yard, but it is equally necessary to segregate the forgings made from this stock until they have been completely heat-treated and are ready to ship to the customer.

Heat-Treatment of Finished Forgings

The necessity for segregation of raw materials as well as segregation throughout the entire process of fabrication can best be demonstrated by our experience on production work. Time and space will not permit of the discussion of the different grades of steels used. The tendency found in the simple carbon-steel summarized in Table 1 holds for all steels, including the more complex alloy-steels. Table 1 gives chemical analyses and physical tests on production work for 107 different melts of a plain carbon-steel purchased under the specification given at the head of the table.

These steels were purchased from a number of different mills and are fairly representative of material selected for our use.

[1] M.S.A.E.—Chief metallurgist, Wyman-Gordon Co., Worcester, Mass.

TABLE 1—CHEMICAL ANALYSES AND PHYSICAL TESTS MADE ON A 0.40 TO 0.50-PER CENT CARBON STEEL

No.	C 0.400 to 0.500	Mn 0.600 to 0.800	P 0.045 max.	S 0.050 max.	Yield-Point, lb. per sq. in.	Tensile-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.
Group A—Drawing Temperature, 980 Deg. Fahr.									
1	0.440	0.730	0.010	0.033	77,150	117,600	19.8	50.5	245
2	0.390	0.630	0.015	0.038	72,875	111,550	20.0	52.1	237
3	0.400	0.620	0.016	0.050	72,700	109,300	21.7	53.0	230
4	0.420	0.680	0.015	0.051	73,600	108,400	18.0	50.3	242
5	0.500	0.580	0.008	0.043	72,000	108,475	19.8	50.7	236
6	0.440	0.670	0.010	0.043	76,800	112,000	21.3	54.9	241
Group B—Drawing Temperature, 1,000 Deg. Fahr.									
7	0.480	0.800	0.015	0.048	76,350	115,600	21.9	53.0	233
8	0.470	0.650	0.009	0.044	76,950	115,425	20.4	50.6	233
9	0.420	0.680	0.019	0.044	76,300	113,200	20.3	53.3	241
10	0.410	0.660	0.015	0.040	78,350	115,950	20.0	52.7	237
11	0.390	0.690	0.0 9	0.042	74,700	110,700	21.6	52.9	238
12	0.420	0.740	0.014	0.038	77,775	115,500	21.9	54.1	236
13	0.430	0.700	0.015	0.039	81,350	122,800	19.6	53.0	241
14	0.400	0.620	0.019	0.035	78,300	117,100	20.3	51.2	238
15	0.480	0.680	0.016	0.034	80,200	118,325	19.8	52.4	238
16	0.410	0.780	0.027	0.042	75,150	112,625	22.2	55.4	241
Group C—Drawing Temperature, 1,020 Deg. Fahr.									
17	0.460	0.740	0.014	0.034	74,575	110,400	21.2	55.8	234
18	0.430	0.740	0.018	0.032	75,625	114,250	21.5	53.3	236
19	0.470	0.630	0.014	0.046	77,200	116,600	22.2	52.5	230
20	0.470	0.630	0.017	0.053	75,450	115,450	20.4	51.7	238
21	0.480	0.730	0.020	0.043	76,250	114,900	21.5	52.6	238
22	0.540	0.630	0.020	0.039	82,400	122,800	21.1	51.5	238
23	0.470	0.740	0.018	0.058	79,200	118,000	22.4	53.8	240
24	0.430	0.590	0.016	0.031	76,400	113,900	22.8	56.0	241
25	0.510	0.750	0.028	0.034	78,450	117,250	21.7	54.5	239
Group D—Drawing Temperature, 1,040 Deg. Fahr.									
26	0.500	0.650	0.022	0.048	78,800	117,370	19.5	50.6	239
27	0.490	0.750	0.015	0.040	77,420	114,200	20.7	51.8	236
28	0.480	0.700	0.024	0.042	78,000	119,400	20.9	52.3	239
29	0.520	0.700	0.018	0.046	76,500	115,600	20.1	53.4	241
30	0.500	0.560	0.022	0.046	75,350	114,175	19.8	51.2	238
31	0.500	0.690	0.018	0.042	79,500	116,350	21.2	53.7	241
32	0.500	0.690	0.016	0.041	76,150	116,350	20.0	50.8	238
33	0.480	0.820	0.019	0.053	79,780	118,500	20.3	52.3	241
34	0.470	0.720	0.015	0.042	75,100	113,900	20.3	50.2	235
35	0.420	0.680	0.019	0.044	76,300	113,200	20.3	53.3	241
36	0.480	0.640	0.022	0.012	77,425	116,125	22.8	54.3	238
37	0.440	0.660	0.022	0.039	79,960	118,120	20.8	53.0	241
38	0.520	0.830	0.031	0.041	77,400	112,900	21.0	55.2	243
39	0.510	0.710	0.042	0.045	78,300	116,600	23.4	55.8	240
40	0.480	0.650	0.024	0.046	79,870	118,200	20.3	52.3	236
41	0.480	0.820	0.025	0.056	76,275	114,800	21.0	52.9	239
42	0.490	0.660	0.026	0.052	78,850	116,600	22.0	52.5	237
43	0.460	0.780	0.009	0.053	75,450	113,125	23.2	56.5	233
44	0.470	0.800	0.014	0.045	77,400	115,500	22.6	55.0	233
45	0.400	0.880	0.010	0.048	76,250	112,850	21.8	55.6	237
46	0.450	0.700	0.036	0.043	74,900	114,000	22.3	53.4	235
47	0.400	0.830	0.026	0.046	79,000	117,400	22.8	55.2	241
48	0.460	0.750	0.017	0.043	78,650	116,750	23.0	56.5	234
Group E—Drawing Temperature, 1,060 Deg. Fahr.									
49	0.500	0.700	0.021	0.043	79,850	118,100	20.7	51.0	235
50	0.450	0.680	0.018	0.054	78,150	116,000	20.3	52.1	241
51	0.480	0.630	0.026	0.042	77,925	116,900	21.6	53.9	241
52	0.470	0.700	0.028	0.040	76,325	113,125	21.3	55.6	233
53	0.480	0.820	0.028	0.053	79,550	117,400	20.4	54.9	240
54	0.470	0.780	0.030	0.042	76,850	115,750	22.1	54.0	237

TABLE 1—CHEMICAL ANALYSES AND PHYSICAL TESTS MADE ON A 0.40 TO 0.50-PER CENT CARBON STEEL (CONCLUDED)

No.	C 0.400 to 0.500	Mn 0.600 to 0.800	P 0.045 max.	S 0.050 max.	Yield-Point, lb. per sq. in.	Tensile-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.
Group E—Drawing Temperature, 1,060 Deg. Fahr. (Concluded)									
55	0.400	0.890	0.012	0.048	76,250	112,850	21.8	55.6	237
56	0.490	0.610	0.013	0.031	73,500	1 7,700	22.9	57.5	233
57	0.470	0.700	0.033	0.031	81,200	119,310	20.8	53.0	243
58	0.4 0	0.780	0.035	0.051	76,870	115,600	22.4	54.5	239
59	0.430	0.650	0.022	0.036	75,950	113,000	23.3	55.5	237
60	0.460	0.690	0.032	0.051	76,600	113,950	22.0	53.6	240
Group F—Drawing Temperature, 1,080 Deg. Fahr.									
61	0.460	0.810	0.017	0.043	79,270	118,500	21.0	54.0	238
62	0.520	0.580	0.026	0.049	76,250	115,900	21.2	56.7	237
63	0.480	0.640	0.022	0.054	77,370	117,100	20.8	52.5	239
64	0.480	0.730	0.034	0.046	80,500	119,900	20.3	50.0	238
65	0.480	0.700	0.033	0.056	79,200	116,500	20.0	53.6	233
66	0.450	0.680	0.018	0.054	77,750	117,150	19.7	51.1	242
67	0.490	0.750	0.026	0.055	77,500	115,900	22.3	55.4	235
68	0.480	0.650	0.025	0.042	79,600	117,900	20.9	52.1	238
69	0.450	0.730	0.027	0.043	82,187	121,000	19.7	51.7	241
70	0.440	0.760	0.025	0.049	79,600	119,[illegible]00	19.9	52.2	242
71	0.450	0.610	0.023	0.040	78,750	114,700	20.7	54.2	245
72	0.460	0.740	0.039	0.040	79,270	115,500	20.5	54.1	242
73	0.480	0.630	0.040	0.043	77,000	113,950	21.1	52.7	247
74	0.460	0.830	0.034	0.047	76,500	113,000	21.4	54.0	246
75	0.490	0.770	0.028	0.041	79,450	118,500	22.4	54.2	237
76	0.430	0.790	0.021	0.043	81,400	120,900	21.6	52.9	241
77	0.470	0.760	0.022	0.046	82,000	121,700	19.5	51.9	242
Group G—Drawing Temperature, 1,100 Deg. Fahr.									
78	0.480	0.730	0.014	0.039	78,250	117,625	21.8	55.9	237
79	0.460	0.730	0.015	0.036	78,350	115,300	21.6	56.0	244
80	0.460	0.690	0.041	0.048	75,100	113,900	20.6	52.2	243
81	0.440	0.760	0.023	0.049	77,100	112,500	21.1	56.2	243
82	0.420	0.790	0.034	0.046	75,200	112,160	22.1	54.5	241
83	0.500	0.660	0.030	0.037	76,970	116,100	20.3	52.8	241
84	0.480	0.690	0.039	0.051	76,600	112,950	21.5	57.0	246
85	0.430	0.920	0.038	0.038	76,200	113,900	24.0	57.3	238
86	0.430	0.810	0.027	0.032	77,900	115,000	23.5	57.2	241
87	0.400	0.850	0.035	0.046	78,600	117,120	22.9	54.6	242
88	0.460	0.610	0.034	0.039	75,650	113,600	23.6	57.6	238
Group H—Drawing Temperature, 1,120 Deg. Fahr.									
89	0.460	0.740	0.039	0.040	79,300	115,500	20.5	54.1	242
90	0.500	0.780	0.033	0.041	82,250	120,650	19.9	55.0	248
91	0.440	0.820	0.028	0.044	78,950	110,500	22.5	59.7	243
92	0.460	0.690	0.032	0.043	81,000	118,750	21.1	53.5	247
93	0.450	0.880	0.036	0.034	79,450	115,950	21.7	57.5	243
94	0.480	0.740	0.033	0.043	77,750	115,200	22.0	54.8	241
95	0.400	0.700	0.033	0.043	74,700	110,000	22.4	57.1	241
96	0.500	0.800	0.035	0.047	82,150	119,300	20.8	54.3	246
97	0.480	0.680	0.025	0.037	77,750	115,850	21.7	56.6	239
98	0.420	0.850	0.038	0.042	77,750	113,550	22.3	59.7	243
99	0.440	0.860	0.031	0.037	78,500	117,000	21.8	57.2	247
100	0.440	0.950	0.025	0.055	75,500	111,100	21.2	57.1	240
101	0.480	0.710	0.033	0.055	80,200	117,900	21.3	54.4	247
102	0.420	0.870	0.035	0.048	83,000	120,625	21.6	54.1	243
103	0.460	0.790	0.036	0.042	81,000	118,425	21.8	54.2	240
104	0.460	0.700	0.035	0.043	79,000	118,000	21.3	52.5	243
105	0.450	0.690	0.029	0.048	75,250	111,500	23.1	56.0	239
106	0.440	0.630	0.028	0.046	76,250	113,650	23.6	57.8	237
107	0.490	0.750	0.026	0.051	78,200	114,800	21.4	56.4	243

The physical properties given in Table 1 are an average of ten tests selected at random for each melt, the tensile test in every case having been made on a prolongation of a crankshaft that was forged to a diameter equal to the maximum section of the shaft. In our practice this coupon remains attached to the crankshaft throughout the various operations and is used as a check on the heat-treatment operations. One or more such tests are provided for each furnace charge, the number depending upon the number of crankshafts in each charge. The diameters used vary from 2¼ to 2¾ in., according to the particular job that is being forged.

The location of test-specimens was in every case at a point halfway between the outside and the center of the coupon. The axis of the test-specimen was always taken parallel to the axis of the coupon from which it was cut. The test-specimen used conforms to the Society's standard dimensions, 0.505 in. diameter and 2-in. gage-length. The tensile tests were all made on a 100,000-lb. capacity automatic and autographic tensile-testing machine, using the 50,000-lb. counterpoise on the beam. spherical-seated grips are used in making all tensile tests. The Brinell hardness number recorded was determined on the crankshaft after first grinding and preparing the surface it does not necessarily indicate the hardness of the test-piece itself.

A study of the results given in Table 1 would lead to the conclusion that the chemical composition of the steel in question is not a complete criterion of the heat-treatment to be specified to meet the requirements of a definite specification. We see that the steels reported require a drawing temperature varying from 980 to 1120 deg. fahr. to bring them within the limits specified. The uniformity of the results obtained in the various groups is exceedingly striking, as is also the uniformity between the various groups.

This latter uniformity is more evident in Table 2 where the averages of the various groups given in Table 1 are summarized. This summary brings out more clearly that the variation in the drawing temperatures necessary to bring these various heats of steel to the common specification cannot be ascribed wholly to the difference in the chemical composition of the heats. The variation in the average carbon and manganese-content of these steels will not account for the large variation in drawing temperatures.

It does not require much play of the imagination to visualize the condition of a charge of steel made up from each of these groups and treated as a single melt. Such, however, is the condition when stock is kept only by size and grade. This condition can also exist in a heat of steel that is intentionally mixed at the mill. The chemistry of the steel, as has been shown, is not a sufficient criterion to allow any person to prescribe heat-treatments with any degree of accuracy. The only safe way to determine this is by actual experimentation for each melt of steel used.

TABLE 2—AVERAGE OF VALUES GIVEN IN TABLE 1

Group	Drawing Temperature, deg. fahr.	C 0.400 to 0.500	Mn 0.600 to 0.800	P 0.045 max.	S 0.050 max.	Yield-Point, lb. per sq. in.	Tensile-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.	Number of Tests Averaged
A	980	0.430	0.650	0.012	0.043	74,280	111,220	20.1	51.9	238	60
B	1,000	0.430	0.690	0.016	0.041	77,540	115,900	20.8	52.8	238	110
C	1,020	0.470	0.690	0.018	0.041	77,300	115,950	21.6	53.6	237	90
D	1,040	0.470	0.730	0.021	0.044	77,500	115,750	21.3	53.3	238	230
E	1,060	0.460	0.710	0.024	0.042	77,420	114,980	21.6	54.3	238	120
F	1,080	0.460	0.710	0.028	0.046	79,100	117,500	20.8	53.1	240	170
G	1,100	0.450	0.750	0.021	0.042	76,900	114,600	22.1	55.2	241	110
H	1,120	0.450	0.770	0.032	0.044	78,800	115,700	21.7	56.0	243	190

The crankshafts represented by these tests were all quenched in water from 1525 deg. fahr., and drawn back to the temperature specified. The furnaces used are automatically controlled, use oil for fuel and have a hearth dimension of 66 x 98 in. The temperatures were all measured by an iron-constantin thermocouple pyrometer system, which was checked constantly by a master pyrometer used exclusively for this purpose. The control mechanism, which is very positive in its action, is responsive to changes of 5 deg. in temperature between fire-off and fire-on. The charge of any furnace can be held for any length of time at any predetermined temperature, without danger of over-running as in hand-fired furnaces. This insures accuracy in heat-treating operations.

The values given in Table 1 have been grouped according to the drawing temperature necessary to meet the following specification

SPECIFICATION OF PHYSICAL PROPERTIES

Yield-Point, lb. per sq. in.	70,000
Tensile-Strength, lb. per sq. in	100,000
Minimum Elongation in 2 In., per cent	18
Minimum Reduction of Area, per cent	50
Brinell Hardness	228 to 248

Testing Finished Forgings

The test applied to finished forgings is a series of either tensile or Brinell-hardness tests, the latter being more extensively used. For quality forgings, both should be used. It is comparatively easy to treat any heat of steel to meet either of these two tests when used separately but, when both conditions are to be met at the same time, the task becomes somewhat more difficult and with some melts of steel it is impossible. When the Brinell-hardness test only is used to test forgings, nothing short of at least one Brinell test on each forging should be countenanced. If this is not done and the various melts of steel used are not segregated throughout the yard and shop, some poorly treated forgings are sure to be the result.

Summary

(1) Steels of the same grade and of the same chemical composition do not respond in the same way to heat-treatment

(2) To heat-treat with minimum loss, only steels from the same melt should be included in a furnace charge

(3) Stock subjected to heat-treatment should be carefully segregated into piles of the same melt; it should be kept segregated throughout the entire process of fabrication to produce satisfactory forgings of uniform quality

(4) Tensile and hardness tests should be required on all heat-treated forgings to check the thoroughness with which the various heat-treatment operations were performed

(5) At least one hardness test should be made on all heat-treated forgings to insure that all have responded to the heat-treatment operations in the same manner

COMMERCIAL-BODY SUPPLY AND SERVICE

(*Concluded from page* 186)

sectional bodies; so that, while much might be done profitably in the standardization of chassis for commercial cars, the situation at present is such as to give the user some latitude in the choice of chassis and at the same time secure the benefits of the standardized body. To only a slightly less extent this condition also holds for 1-ton trucks. All this has been accomplished, not because of recognized standards, but in spite of the absence of such standards.

Trucks of greater capacity have not been produced in sufficient quantity in any one make or model to give the standardized heavy-duty truck-body a fair chance. While the advance already attained in the commercial and light-truck business serves to emphasize the pressing need for truck-body standardization, this standardization cannot be carried out successfully until the truck chassis has been standardized. It is doubtful whether any single step could be of more immediate advantage to the truck industry than standardizing chassis body-mounting dimensions, thus enabling body production to be put on a manufacturing basis. There is now a vast difference in all chassis dimensions that have to do with the fitting of the body, such as frame widths and lengths, rear-wheel dimensions, wheelbases, driver's seat and its location and all controls. Standardizing frame widths and rear-wheel dimensions would help the body-builder most, but the length of the frame back of the driver's seat and the distance from the driver's seat to the rear axle should be given attention at the same time, establishing, say, a range of three lengths for each body-capacity. If, in addition to a uniform practice in these dimensions, agreement could be effected on a standard difference between the height of the frame from the ground and the diameter of the rear wheel for each capacity of truck, the heavy-duty body-builder would be able to count on a sufficient volume of demand to justify marketing standardized bodies for these trucks, and the truck builder, the dealer and the user would enjoy all the advantages that now accrue only in the commercial car and light-truck field.

By such a process of standardization, not only the body-builders, but all suppliers of material to them could adopt standards that would reduce their costs greatly, and so through every process of the body industry effect remarkable savings. The delivery to the dealer of the mounted body could be made immediately from stocks of bodies, including a wide range of styles, carried by body-builders having branches, or distributors, throughout the country. There would be an enormous elimination of waste through the user getting his truck and body into profitable operation without any loss of time and continuing their use without expensive lay-ups for repairs; all on account of the superior service all along the line that can be made possible only by the standardization of such chassis dimensions as affect body mounting.

1922 SUMMER MEETING

WHITE SULPHUR SPRINGS, W. VA.

JUNE 20-24

As this issue of THE JOURNAL goes to press, the Meetings Committee of the Society announces the selection of White Sulphur Springs, W. Va., as the location of the 1922 Summer Meeting. Rates, reservation blanks and a description of this unusually attractive resort will soon reach the members in *The Meetings Bulletin.*

Highway Transportation as It Affects the Automotive Engineer

By E. W. TEMPLIN[1]

PENNSYLVANIA SECTION PAPER *Illustrated with* PHOTOGRAPHS AHD CHARTS

STATING that the means and methods of transporting freight over the highways are governed by six factors, the author enumerates them as being the number of ton-miles of goods to be shipped, the shipping points and destinations, the kinds of highway available, the types of vehicle most suitable, the cost of operation per ton-mile and the rates that should be charged for the service. The purpose of the paper is not to answer these questions but to determine if present practice is headed in the right direction.

The conditions the highway must meet, in addition to the gross load of the vehicles, are the maximum tire load, the pressure per square inch exerted by the tire upon the pavement and the value of any impact blow upon the pavement. The impact blows of pneumatic tires are practically negligible, while solid tires build up the impact to many times the weight of the wheel load; this is proved by impact tests of tires which are described in some detail and illustrated.

The state of development of the pneumatic truck tire and average mileage obtained by its users are treated specifically, spring suspension and steering are discussed, a summary is presented in three divisions and an appendix, giving three specific results of tests made by the Bureau of Public Roads on the six-wheel truck the author describes, is included.

HIGHWAY transportation is being recognized as a way of augmenting other present means for transporting goods. It offers a large field when the possible magnitude of the ton-mileage that can be delivered over the highways is considered. The means

FIG. 1—BEAM-TESTING MACHINE EMPLOYED IN MAKING IMPACT TESTS OF SOLID AND PNEUMATIC TIRES

and methods for transporting freight over the highways are governed by the following factors:

(1) Number of ton-miles of goods to be transported
(2) Shipping points and destinations
(3) Kind of highways available
(4) Types of vehicle most suitable
(5) Cost of operation per ton-mile
(6) Rates that should be charged for the service

The purpose of this paper is not to answer these questions but to determine if present practice is headed in the right direction. Quoting from *Good Roads*

FIG. 2—CLOSE-UP VIEWS OF A 6-IN. SOLID TIRE AT THE LEFT AND AN 8-IN. PNEUMATIC TIRE AT THE RIGHT BEING PRESSED OVER A 70-LB. RAILROAD RAIL

> Almost every day brings a new example of the dependence upon motor trucks for the transportation of goods. Foodstuffs are hauled from the farms to markets, lumber is brought out of the forests, raw materials of one kind and another are carried to the factories and manufactured articles are distributed to wholesalers and retailers. Much of this business is of the short-haul variety, but a considerable portion is long-distance hauling. Regular routes of 500 to 600 miles no longer attract general attention. This development of truck hauling is due to the growing appreciation of the advantages of highway transportation. In view of the ever-increasing demand for long-distance truck-hauling it seems self-evident that there is a greater need than ever before for the betterment of the highways. If trucks are to render anything like the maximum service of which they are capable, at least passable roads must be provided for their operation.

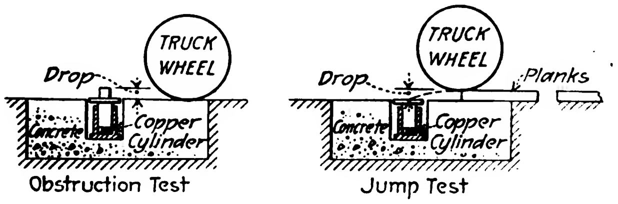
Quoting again the same source we find that, by the use of highway transportation, production can be increased, costs reduced and an increased revenue to the producer assured.

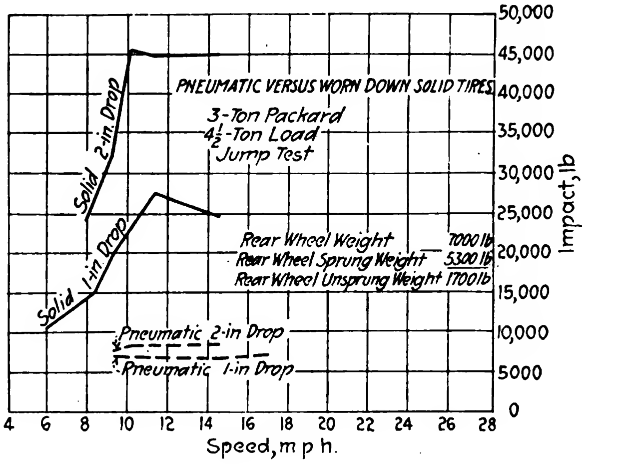
> It is possible to double farm production by saving what is now wasted. This makes possible a wider producing area and assures the prompt arrival of perishable goods at the door of the consumer when they are in the best condition and command the highest price.
>
> It is necessary that good roads be available 365 days of the year. This involves a system of snow removal. During the war snow removals under State and National direction were organized. This work could well be continued now, especially in keeping open that 20 per cent of roads on which 90 per cent of highway traffic is concentrated.
>
> The automotive industry recognizes the menace to the highways of excessively heavy trucks, and advocates that no vehicle weighing more than 28,000 lb. gross load shall be permitted the use of the public high-

[1] M.S.A.E.—Motor-truck engineer, development department, Goodyear Tire & Rubber Co., Akron, Ohio.

way as at present constructed. It believes also that the increasing use of pneumatic tires on trucks will reduce the damage. We are equally convinced that the highways of the future should be the servants of transportation, not its master. They should be prepared to accommodate a constantly increasing volume of haulage carried by trucks of whatever size that shall prove most swift, efficient and economical.

The conditions the highway must meet, in addition to the gross load of the vehicles, are the maximum tire load, the pressure per square inch exerted by the tire upon the pavement and, since there are irregularities in any kind of pavement, the value of any impact blow that the tire may exert upon the pavement. Pneumatic truck tires do not in any measure reduce the maximum load per tire, but they decrease the pressure per square inch upon the pavement. They present twice the area of contact on the pavement that solid tires of corresponding capacity present. More important, however, is the fact that the impact blows of pneumatic tires upon the pavement are





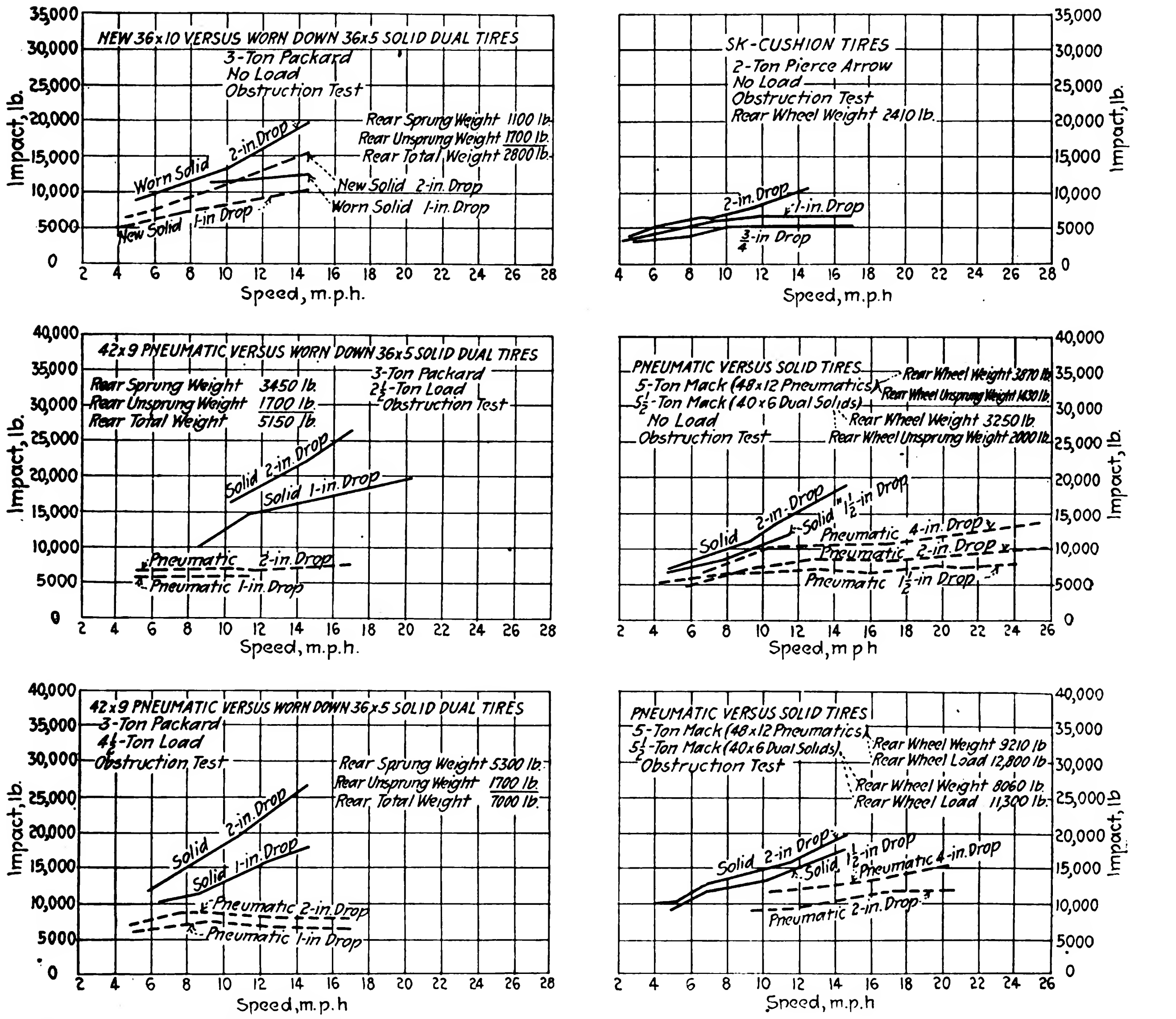


FIG. 3—RESULTS OF TESTS OF VARIOUS SIZES OF TIRES CONDUCTED BY THE BUREAU OF PUBLIC ROADS OF THE DEPARTMENT OF AGRICULTURE

practically negligible, while solid tires build up impact blows to many times the weight of the wheel load. The truth of this statement is evidenced by the following tests.

Impact Tests of Tires

A 6-in. solid tire was compared with an 8-in. pneumatic tire, since in practice they are used to carry corresponding loads. Each tire was placed in a beam testing machine, as indicated in Figs. 1 and 2, and a load was gradually applied so as to depress the tire over a 70-lb. railroad rail. Readings of the load and the corresponding depression were taken at regular intervals. Under a 7000-lb. load the new solid tire deflected 0.7 in., but the corresponding 8-in. pneumatic tire deflected 3.4 in., or 4.9 times as much. However, for consideration of tire effects upon the highway, the worn solid tire should be the one considered. The three-quarter-worn solid tire about 1 in. thick depressed only 0.3 in. under a 7000-lb. load and the corresponding pneumatic tire depressed 3.4 in., or slightly more than 11 times as much. These same tests were repeated with a 12-in. solid tire against a 12-in. pneumatic tire. It was found that practically the same proportions hold.

A. F. Masury has taken advantage of the Novograph motion-picture machine to study the depression of pneumatic as compared with solid truck tires. The very ingenious method of having the trucks leap into the air and come down against the pavement was used. This without doubt introduces the most extreme stresses. In his conclusions[2] he compares two trucks of the same capacity and design, one equipped with presumably new solid tires and the other with pneumatic tires. Each had the same amount of load and each attained the same speed at the leap. The force with which the solid-tired truck struck the ground was 14,336 lb. for unsprung parts as against 4624 lb. with the pneumatic-tired truck. The force from the sprung parts was 13,014 lb. for the solid and 9282 lb. for the pneumatic-tired truck. The deflection of the pneumatic was 4.5 times that of the solid tires. This checks closely with the Goodyear company test showing 4.9 times as much deflection for a pneumatic tire as for a new solid tire. If Mr. Masury had made his trials with worn solid tires, he would, no doubt, have found that the pneumatic tire depresses about 11 times as much as the worn solid tire; therefore, the worn solid tire introduces enormous stresses into the structure of the highway pavement.

Still another class of tests is now in process and has an important bearing on this question. The tests are being conducted by the Bureau of Public Roads of the Department of Agriculture, under the direction of A. T. Goldbeck and E. B. Smith. They are made by running various trucks over a certain stretch of highway and artificial means are provided for causing the wheels to drop given distances. The force of the impact on the road is measured by the compression of standardized copper cylinders. Curves plotted from the data obtained in these tests are shown in Fig. 3. In all but one case the test was made on the same type of truck equipped first with solid and then with pneumatic tires. In the test on the 5-ton capacity truck a chain-driven solid-tired truck was run against a truck of the same make equipped with pneumatic tires but driven by a double-reduction gear. This introduced some difference in the weight of unsprung parts, but it was noted in each case. The conclusions that can be drawn from these tests are that

(1) With solid tires the force of the impact increases rapidly with an increase in speed; whereas with pneumatic tires the force increases only slightly with a large increase in speed
(2) Pneumatic tires give only one-third to one-fifth the impact force of solid tires
(3) A 5-ton truck on pneumatic tires can travel 24 m.p.h. with the same impact effects that a solid-tired truck having new tires will cause at 8 m.p.h.
(4) The value of the impact force with pneumatic tires is only from 1000 to 1500 lb. greater than the wheel load. With the worn solid tire the impact force became 38,000 lb. greater than the wheel load of 7000 lb. at a speed of only 10 m.p.h. over a drop of 2 in., in the test of a 3-ton truck

It appears, therefore, that we have found definitely the cause for the destruction of our highways. Without doubt, if the highway engineer is asked to design a pavement to carry solid-tired trucks, he necessarily must consider the forces introduced by the worn solid tire as the maximum force which the pavement must withstand. Also, if he designs a highway to carry pneumatic-tired vehicles, he should be able to design one that will cost much less money than one designed to carry solid-tired vehicles. I have serious doubts if this country, wealthy as it is, can afford to build properly the highways required for carrying motor trucks equipped with solid tires, especially when the enormous stress introduced by the worn solid tire is taken into consideration.

The Pneumatic Truck Tire

In regard to the state of development of the pneumatic truck tire and the average mileage secured by its users, Table 1 gives an analysis of 500 trucks and covers the average mileage secured.

TABLE 1—PNEUMATIC TRUCK TIRE CARRYING CAPACITY AND MILEAGE[3]

Size of Tire, in.	Carrying Capacity, lb.	Average Mileage
6	2200	14,026
7	3000	14,791
8	4000	12,782
9	5000	12,028
10	6000	11,317
12	9000	Still experimental

[3] Analysis of 500 truck performances.

It is generally conceded that pneumatic truck tires will not withstand overloading successfully. The matter of introducing the larger sizes, 10 and 12 in., introduces new problems, including those of service, availability of necessary air pressure and the disposition of the driver in the matter of taking care of the equipment. The 10-in. tire is giving very satisfactory service where it is properly handled, although it is a heavy and costly tire. The 12-in. tire is giving very gratifying results from the mileage standpoint, but it appears to be too high a tire, too heavy and too costly to give general satisfaction. On this account we feel that there is good reason for experimenting with the application of four small-size tires to replace the two 12-in. rear tires. Since there are many objections to the use of dual pneumatic tires in the sizes above 5 in., applying the tires in tandem seemed advisable. We therefore constructed a motor truck throughout, to determine the practicability of this kind of tire application it is shown in Fig. 4. This is a pneumatic-tired truck of 5-ton capacity. Brief specifications are

[2] See The Journal, July, 1920, p. 96.

FIG. 4—PNEUMATIC-TIRED TRUCK OF 5-TONS CAPACITY IN WHICH TWO 12-IN. REAR TIRES HAVE BEEN REPLACED BY FOUR SMALL-SIZE TIRES

given below. The mileage obtained from the different trucks built is given in Table 2.

Wheelbase—From the center of the front wheel to the center between the two tandem rear wheels, 180 in.
Tires—Pneumatic all around, size 40 x 8 in.
Engine—Four-cylinder 5 x 6 in. Hercules; Model T-3-40 hp. (N. A. C. C.); 3200 lb.-in. torque at 1200 r.p.m.
Ignition—Philbrin
Radiator—Modine Spirex.
Transmission—Brown-Lipe, Model 60-UPP and Auxiliary
Clutch—Brown-Lipe, Model 60, multiple-disc
Speeds—Six forward; two reverse
Gear Ratios—

Low, 82.0 to 1	Fifth, 10.0 to 1
Second, 35.7 to 1	Sixth, 5.8 to 1
Third, 23.2 to 1	Low reverse 99.5 to 1
Fourth, 20.1 to 1	High reverse 28.4 to 1

Rear Axles—Two, Standard Parts; Model 603; worm drive arranged in tandem; ratio 5.8 to 1. Equipped with four 21-in. diameter brakes of 5½ in. width; in pairs, 2¾ in. wide.
Fuel and Oil Capacity—Gasoline, 67 gal.; oil, 10 gal.
Turning Radius—35 ft.
Chassis Weight—8500 lb.
Normal Speed—25 m.p.h.
Maximum Speed—In tests under full load on a level road, 45 m.p.h.
Body—Haskelite plywood, weight 2000 lb. Loading compartment 15 ft. long, 6 ft. high, 7 ft. wide; contains sleeping compartment, toolbox and compartment for two spare tires and other parts; sides and partitions, 5/16 in. thick; roof ⅛ in., covered with 4-oz. duck

TABLE 2—SIX-WHEEL TRUCKS BUILT AND MILES OPERATED[4]

Truck No.	Miles Operated
X-1	12,000
X-2	10,000
X-3	5,000
X-4	900
X-5	Now being built

[4] The chain, worm and internal-gear axles of these trucks are now being tested.

This new type of truck is offered as a solution of the problem of suitable pneumatic tires on trucks of 5-ton capacity and upward, where

(1) Greater speeds than those advisable with solid tires are desired
(2) Greater protection to the merchandise carried is necessary
(3) High speeds and heavy loads will not work injury to the roads
(4) The comfort of the driver is a consideration
(5) A low center of gravity is desired
(6) Safety demands additional braking capacity
(7) Bad roads now interfere with economical operation
(8) Simplicity of tire change, low tire cost, economical operation and a broadening of the field of highway transportation are necessary

SPRING SUSPENSION AND STEERING

Two types of spring suspension are being used in our experiments. The one shown in Fig. 5 consists of a single spring on each side of the chassis; it is inverted and pivoted to the chassis frame and rests on spring bolts in brackets fastened to the axle housing. The axles are held in place by crossed tie-rods, which permit the lengthening and shortening of the spring. This type is giving satisfactory results.

The type shown in Fig. 6 consists of two springs on each side of the chassis frame. These are bound together and pivoted to the chassis frame. This construction does not involve the tie-rods but does require that the springs be fastened pivotally to the axles, to permit the necessary flexibility for the latter when an irregular road contour is encountered. This general method of pivoting the rear-axle assembly gives unusually good riding qualities.

How the truck steers around corners is hard to explain. This can be partially understood from Fig. 7, which shows that the high pneumatic truck-tire section permits the tire to deflect sidewise and that it is thus allowed to take the curve gradually without slipping and wearing the tread. We have not worn out any tires on this six-wheel truck as yet, but the condition of the tires now in use indicates that we can expect 10,000 to 12,000 miles of service from the rear tires.

When operating this truck alone with a 5-ton pay load, a total weight of 21,000 lb., over the brick highway between Akron and Alliance, Ohio, a distance of 120 miles, the average speed was 23.9 m.p.h. and the average gasoline consumption 6 miles per gal. When operating this truck with a trailer attached as shown in Fig. 10, each vehicle being loaded with 5 tons and constituting a total pay-load of 10 tons or a gross load of 37,000 lb., over the same highway and a distance of 125 miles, the average speed was 16.8 m.p.h. and the average gasoline consumption 2.8 miles per gal.

These performances indicate good possibilities for attaining a 48-hr. motor-truck express service between Akron and New York City, the distance by highway being 500 miles. The present express rate for goods shipped

FIG. 5—A TYPE OF SPRING SUSPENSION CONSISTING OF A SINGLE SPRING ON EACH SIDE OF THE CHASSIS, THE SPRING BEING INVERTED, PIVOTED TO THE CHASSIS FRAME AND RESTING ON SPRING BOLTS IN BRACKETS FASTENED TO THE AXLE HOUSING

Fig. 6—A Spring Suspension Consisting of Two Springs Bound Together and Pivoted to the Chassis Frame

from Akron to New York City is $2.84 per 100 lb., or $56.80 per ton. Therefore, a 5-ton truck that can operate within 56.8 cents per mile and average 20 m.p.h. can, at express rates, give better service than that of the railroad express company.

Summary

(1) Past experience and recent tests prove that the solid-tired truck is an extremely uneconomical factor in highway transportation, from the fact that it is unquestionably destroying present expensive highways; and that it will destroy any highways constructed in the future, unless they are built about five times the present strength, at about three times their present cost
(2) Pneumatic truck tires are proving their practicability
(3) It appears possible to design a vehicle that will have many mechanical advantages and only require a pavement designed and built for carrying and withstanding the shocks of a loaded 9-in. pneumatic truck tire. This combination of vehicle and highway would permit a pay-load capacity of from 5 to 7 tons. Even with this heavy tonnage capacity this type of truck would have less of a destructive effect upon the highway than present light solid-tired trucks, and it would be very economical to operate from the standpoints of fuel consumption, tire, maintenance, and highway costs

Since the paper was presented, the six-wheel truck referred to has been tested by the Bureau of Public Roads with the following results:

Fig. 7—How the High Pneumatic Truck-Tire Section Permits the Tire to Deflect Sidewise, Thus Enabling a Truck to Turn Corners Without Slipping and Wearing the Tread

(1) The impact delivered by the six-wheel truck loaded with a 6-ton pay-load was equal to the impact delivered by an ordinary 2-ton truck having a 2-ton pay-load
(2) The bearing pressure upon the highway pavement is at a maximum under each of the rear wheels, giving a soil pressure of approximately 3 lb. per sq. in., maximum, with a 6-ton pay-load as against 6 lb. per sq. in. for an ordinary 5-ton truck with a 5-ton pay-load
(3) The maximum impact delivered by the six-wheel truck with a 9-ton pay-load was approximately 10,000 lb., as against a maximum blow of possibly 70,000 lb. delivered by an ordinary 5-ton truck with a 7½-ton pay-load

THE DISCUSSION

Chairman G. W. Smith, Jr.:—How about the shock effects on the springs themselves?

W. M. Newkirk:—I think that the six-wheel construction should be easier on the spring than the usual construction on the four-wheel trucks.

Chairman Smith:—I had in mind the abnormal obstruction which, as Mr. Templin states, causes a 45,000-lb. impact.

Mr. Newkirk:—The spring does not get that amount of shock. I understand that is the measure of the impact between the tire and the road.

Chairman Smith:—But the difference in the impact of the load would be very considerable, due to the spring.

Mr. Newkirk:—It is the actual force exerted on the road surface which is considered. The shorter the space is in which that force is counteracted, the greater the pressure is. I understand that this force can be measured fairly accurately by the method of compressing those copper cylinders.

Chairman Smith:—The matter of work done enters the problem, as well as that of force.

Mr. Newkirk:—It is entirely a matter of work done. The effective pressure on the road surface, at the instant of passing an obstruction, is made up principally of two factors, the static load and the impact of the unsprung parts of the car. This latter should be thought of as "work" rather than pressure. We have a mass which must either be suddenly lifted, if passing over an obstruction, or whose vertical motion must be suddenly stopped, if dropping over the edge of a hole. At the instant of contact, the road surface pressure will increase, the amount of increase depending very largely upon the yielding character of the tires and the road surface. The greater the compressibility of the tire is, the greater the distance is through which the vertically moving parts will be acted upon by the force required to bring them to rest and, consequently, the smaller this force will be. The relative incompressibility of solid rubber tires as compared with pneumatic tires makes it self-evident that with pneumatic tires the pressure effect upon the road must be decidedly less harmful.

The impact of the sprung load is not a serious matter, as the springs under anything like normal conditions will always yield so freely that but little increase in road pressure can be produced. As a general proposition, the more flexible the springs are, the less the road pressure effect will be.

A. K. Brumbaugh:—Mr. Masury's figures appear optimistic because he was dealing with forces due to impact and measuring them by a moving picture machine set some distance away. What sort of ground or under what condition did Mr. Masury make his tests? Were they made on a non-compressible surface, or were they made on earth?

E. W. TEMPLIN:—I do not know. His report mentions the compression of the tire as well as the depression in the pavement.

MR. BRUMBAUGH:—I believe 14,336 lb. was specified as the striking force of the solid tires. How can he be so exact? In connection with the figures given for the solid-tired truck, undoubtedly the impacts are far greater than with the pneumatic tires, but the figures predicated on too bad a road. If the depressions in roads are measured, it will be found that they are much less than they appear to be. The 2-in. drop represents a rather healthy hole in the road; some are deeper, but not all roads have 2-in. holes. We have some far better roads than that. The utmost destructive effect on roads is caused by the concentrated wheel load which is not helped out by either the solid or the pneumatic tire. All the roads were broken to pieces about the spring of 1918. Roads laid with 8 to 10 in. of concrete that was not reinforced were broken. Invariably, on the hillsides and at soft places, the breakage was due to the sub-grade of the road, and not to raveling effects or impact of tires. On every hillside, on which springs normally occur, and in places where through lack of men and funds it has not been possible to keep the ditches open, the roads have failed, there being a soft wet spot beneath the point of failure. Undoubtedly, a heavy raveling effect is caused by solid tires, but I believe that the pneumatic tire running at from 30 to 40 m.p.h. is not innocent of that effect either. When pneumatic tires are new and the lugs are on, they may not damage the road in this manner, but I believe there is a strong suction effect later which does cause raveling. I believe that there is very little more impact with solid than with pneumatic tires on an ideal road surface. On bad roads solid tires cause some additional impact and the pneumatic tire gives better results.

The matter of wheel load is a large factor, and is recognized by highway engineers first in building roads of reinforced concrete. Roads surfaced with large reinforced-concrete slabs hold together better under an improper sub-grade condition. Engineers recognize wheel load in the limitation of the total weight that is allowable on four wheels; that is 28,000 lb. In Pennsylvania it is 26,000 lb. and roads built with 8 to 10 in. of plain concrete not reinforced will not stand up, unless the subgrade is in perfect condition, the ditches open and the road adequately drained. These roads are torn to pieces by excessive loads. In addition to load, on an ordinarily poor road, if the truck mires and the driver has power enough to rotate the rear wheels, he will put only one chain on, if he thinks he can avoid using two, and try to dig out in that way; finally, he may be forced to use some other means to get out. That is typical of the road between Philadelphia and New York City, which probably carries heavier truck traffic than any other road in the country. The traffic is enormous and this road is torn to pieces by heavy motor trucks, as soon as it becomes somewhat bad or soft, either by sliding off to one side of the road or by digging holes right in the road.

CHAIRMAN SMITH:—Mr. Brumbaugh makes three points; that damage due to loads is a matter of sheer weight in many cases, that pneumatic tires have a raveling effect due to suction, and that the 2-in. arbitrary fall mentioned in Mr. Templin's paper is rather a pessimistic view to take of general conditions. Incidentally, a certain amount of damage is due to the slippage of wheels and to tire chains.

G. H. WOODFIELD:—I think that Mr. Templin did not attempt to use 2 in. as the average fall; he used that distance simply to point out the relationship between solid and pneumatic tires.

MR. TEMPLIN:—Referring to the 45,000-lb. impact for the 2-in. drop in Fig. 5, note that for 1 in. the impact value goes up to 27,500 lb., which is practically 20,000 lb. above the static wheel load. That will give a basis for judging what value the civil or the highway engineer should take in designing pavements. Notice also that the maximum value for the solid tire occurs at about 11 m.p.h. The pneumatic tire was run up to 17 m.p.h. and the impact value is scarcely above the static wheel load. These tests are not as yet completed. These data are for a 3-ton truck; the data for a 5-ton truck with the tires worn down will be equally interesting. The figures given are for a 5-in. dual solid and for a 9-in. pneumatic tire.

MR. BRUMBAUGH:—What is the area of the tire on the ground?

MR. TEMPLIN:—The area of the 9-in. pneumatic tire on the ground is 50 sq. in. for each tire; the area of the solid tire no doubt would have been about 25 sq. in. Solid tires average practically one-half the area of the pneumatic tires, on the ground.

MR. BRUMBAUGH:—Were all the measurements in the tests made by the copper-cylinder method?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—What total amount of compression is involved in the copper cylinders? Is it large enough to take care of any moderate difference of impact? I judge that it is a very small fraction of an inch, so that a few thousandths of an inch would correspond to a great many thousand pounds of impact.

MR. TEMPLIN:—These cylinders are calibrated very carefully.

MR. BRUMBAUGH:—Regarding uniform composition of the copper?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—Are they calibrated by impact?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—Even at 45,000 lb., that is a severe blow. If they have only 25 sq. in. per tire, that would give a 50 sq. in. total on the ground, or certainly not under 45 sq. in. Was 45,000 lb. the value stated for one wheel?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—Certainly there must be more than 25 sq. in. of tire surface on the road, with a 45,000-lb. impact.

MR. TEMPLIN:—That applies to a worn solid tire having only about 1 in. of rubber on it.

MR. NEWKIRK:—Undoubtedly that amount of impact is terrific.

MR. TEMPLIN:—Concrete pavements begin to fail at the joints. Even a ¼-in. drop will start the joint chipping off at the edges. As that drop increases to 2 in., even if it does not become greater, that is enough to break the joint down.

MR. BRUMBAUGH:—I have watched concrete road failures. It will be found that 90 per cent of them are due to a total breaking up of the road. If it is a well-laid concrete road, when it fails this is usually caused either by temperature cracks or cracks due to the failure of the sub-grade, although there is some raveling at the expansion joints. Once the sub-grade fails, it just breaks to pieces. On the Pennsylvania and Maryland roads on every hillside the concrete is being broken into chunks. Generally, the surface is good; there is no evidence of small detail failures throughout the surface, except on the

(*Concluded on page* 226)

Spectroscopic Investigation of Internal Combustion

By Thomas Midgley, Jr.[1] and W. K. Gilkey[2]

Annual Meeting Paper — *Illustrated with* Diagrams and Photograph

THE paper is designed to familiarize automotive engineers with the general subject of spectroscopy, pointing out the various methods that can be employed to determine the actual instantaneous pressures obtained in normal combustion, the temperature-time card of the internal-combustion engine and the progress of the chemical reactions involved in normal and abnormal combustion.

The subject of spectroscopy is outlined and explained, illustrations being presented of different types of spectra, and spectroscopes and their principles are discussed.

The remainder of the paper is devoted to an outline of what the spectroscope can reveal about the nature of combustion.

THE spectroscope has contributed more knowledge to man concerning the nature of the universe in which he lives than any other single piece of scientific apparatus. It is possible to determine by its use the velocity with which the heavenly bodies are either approaching or receding from the earth, the temperatures of these bodies, the elements of which they are composed and the state of matter in which these elements exist. For example, the element helium was discovered in the atmosphere of the sun some 27 years before it was found to be existent on the earth. The spectroscope has played an even more important part in the realm of the infinitesimal. For example, it is possible to detect in the flame of a bunsen burner 1/80,000,000 mg. of lithium, an amount that defies all other methods of detection. Moreover, the X-ray spectroscope has given us an entirely new conception of the constitution of matter. With such an instrument available to the automotive engineer, it is remarkable that he has never made use of it to study the most fundamental problem of internal-combustion engineering; namely, internal combustion itself.

It is not the purpose nor is it within the scope of this paper to present data that will settle definitely any of the disputed points concerning combustion. This result can be accomplished only after years of serious research by many investigators. It is our purpose, rather, to present to the automotive engineer a brief outline of spectroscopy and to point out the various methods that can be employed to determine the actual instantaneous pressures obtained in abnormal combustion, the temperature-time card of the internal-combustion engine and the progress of the chemical reactions involved in normal and abnormal combustion.

Spectroscopy

Spectroscopy is the resolution of light into its component parts and the study of these parts. As an example, of two different lights, both may appear white to the eye; but the spectroscope may reveal that one as a hot incandescent solid and that the other is a gas electrically excited.

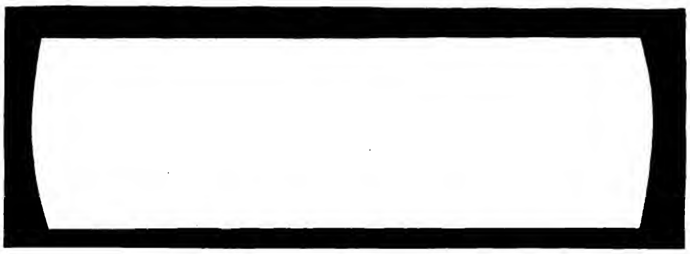


Fig. 1—Examples Reading from the Top Down of the Continuous, Line and Banded of Fluted Spectra

The three distinct kinds of spectra are the continuous spectrum, the line spectrum and the band or fluted spectrum. An electric light gives a continuous spectrum; that is, one containing all wave-lengths and having no discontinuities. At one end it is red; the red color blends into orange, the orange in turn blends into yellow, the yellow into green, and so on. On the other hand, a mercury-vapor lamp gives a spectrum consisting of only a few lines, of which two yellow ones, close together, a green and a violet, are most easily seen. If we examine the spectrum given by a carbon arc, we find that it is continuous with bright flutings superimposed at certain places. Fig. 1 shows examples of continuous, line, and banded or fluted spectra in the order named commencing at the top of the illustration. Continuous spectra are typical of hot incandescent solids and liquids. Line spectra are given by a spark passing between metals or by an elemental gas at low pressure and electrically excited. Fluted spectra are given by gaseous compounds under various conditions.

There is another type of spectrum that may be mentioned, although it probably has little bearing on internal-combustion work. When a white light is caused to

[1] M.S.A.E.—Chief engineer, fuel research section, General Motors Research Corporation, Dayton, Ohio.

[2] Research engineer, fuel section, General Motors Research Corporation, Dayton, Ohio.

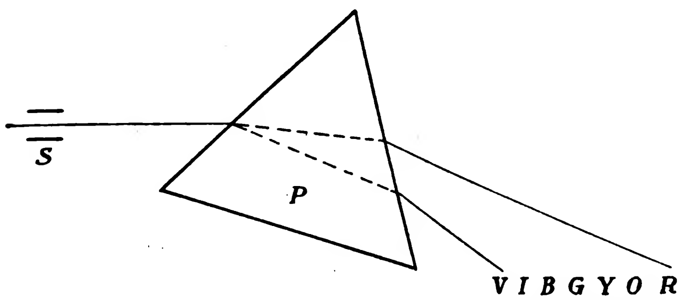


FIG. 2—DIAGRAM ILLUSTRATING THE SIMPLEST FORM OF SPECTROSCOPE

pass through a gas that fills the space between it and the slit of the spectroscope, a spectrum is obtained that is continuous except for a number of dark lines crossing it. These dark lines have the same wave-lengths as those that the gas would emit if electrically excited in a nearly evacuated tube. The dark lines indicate that the gas has absorbed the light that has the same wave-lengths as the gas would emit if it were made the source of light. Such spectra are called absorption or dark-line spectra. The continuous spectrum from the sun is crossed by thousands of these lines, called Fraunhofer lines from the name of their discoverer. They indicate that the atmosphere of the sun is composed of gases and the vapors of metals that are cooler than the solid body of the sun, and that these gases and vapors have absorbed from the original light those colors having wave-lengths characteristic of the emission spectrum of these substances. For this reason, it is easy to analyze the atmosphere of the sun by the spectroscope.

SPECTROSCOPES

An instrument for producing a spectrum and investigating it is called a spectroscope. The simplest form of spectroscope consists of a glass prism that receives from a narrow slit the light to be investigated. When it emerges from the prism, this light is spread out as is shown in Fig. 2, in which S is the slit, P is the prism, and the letters *V I B G Y O R* stand for violet, indigo, blue, green, yellow, orange and red light, respectively.

Red light has the longest and violet light the shortest wave-length of the visible spectrum. The visible spectrum extends from 0.40 micron to 0.76 micron; 1 micron equals 0.001 mm. But beyond the violet is the ultra-violet, which extends to 0.10 micron; and beyond the red is the infra-red, which extends to 200 microns; and far beyond this even are waves of the same character, differing only in that they have longer wave lengths.

A prism is not the only means of separating light into its component parts. Several other methods are available, all of which have their limitations. The diffraction grating is the only one of these that need be considered here. A grating is a piece of metal or glass on which several thousand lines per inch have been ruled with a diamond point. The grating used in our work is of speculum metal ruled with 15,000 lines per in. A grating acts in a manner similar to that of the prism, producing the same kind of spectrum except that the grating can spread light out into a spectrum that is several times as long as that formed by a prism. Fig. 3 is a diagram of the optical system of one of our spectroscopes that was designed and built by Prof. H. C. Lord, of Ohio State University. Fig. 4 is a photograph of this spectroscope. Note that this instrument has both a prism and a grating, and that these are arranged so that the effect of one is added to that of the other.

[2] See Spectroscopy by E. C. C. Baly, p. 636.

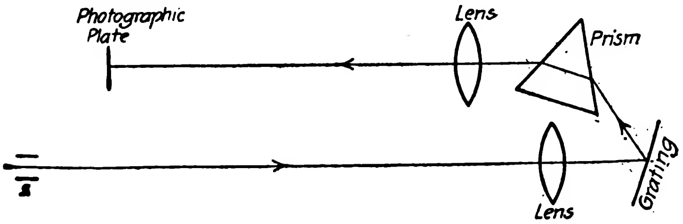


FIG. 3—DIAGRAM OF THE OPTICAL SYSTEM OF THE SPECTROSCOPE USED BY THE AUTHOR

SPECTROSCOPIC ANALYSIS

Three things about an explosion in an engine can be determined with a spectroscope; that is, the pressure, the temperature and the chemistry of the combustion. It should be borne in mind that it is only possible for the spectroscope to do this because it has no moving parts and makes use of light alone, which has no inertia; so, any combustion condition is instantaneously recorded.

The pressure can be determined by the shift of the sodium D lines that is due to pressure. This pressure-shift has been thoroughly investigated by Humphreys, who found that a rise in pressure of 12 atmospheres increased the wave-length of these lines 0.108 Angstrom unit (1 Angstrom unit $= 10^{-7}$ mm.), and thus shifted them toward the red end of the spectrum.[2] There is always enough sodium in the air entering the cylinder to give these sodium lines; hence, it is only necessary to photograph a stroboscopic spectrum of the light coming from the engine to obtain a record of any shift of the sodium lines. Since Humphreys proved that the shift is directly proportional to the absolute pressure, the pressure can be calculated from the amount of this shift. Fig. 5 shows what might be expected on a photograph if a very high pressure existed for a third of the combustion stroke.

FIG. 4—PHOTOGRAPH OF THE SPECTROSCOPE SHOWN IN DIAGRAMMATIC FORM IN FIG. 3

The temperature can be determined in accordance with Wien's law, which states, for a perfectly black body, the wave-length of maximum energy is inversely proportional to the absolute temperature. Unfortunately, except for extremely high temperatures, this maximum is in the infra-red where observation is difficult on account of the limitation that the light cannot be allowed to pass through glass because it absorbs the infra-red rays. It is necessary, therefore, to use a quartz window in the cylinder and a rock-salt prism in the spectroscope, and to do the focusing by spherical mirrors instead of lenses. The spectral rays are received on a thermopile that actu-

(*Concluded on page* 222)

A Super-Machine-Gun

A MACHINE-GUN far more powerful than any other similar weapon heretofore used has been developed recently for army service. This is known as the Browning 0.50-caliber machine-gun. It is without doubt the most important and interesting development in the small-arms field since the world war, and perhaps one of the most interesting in the whole field of ordnance. In August, 1914, the caliber of the standard machine-gun of each nation was the same as the caliber of the infantry weapon of that nation, and in most instances they fired identically the same ammunition. The principal rôle assigned to machine-guns at that time was that of supplementing rifle-fire against targets assigned to the infantry and the cavalry.

One of the first departures from the prewar conception of the proper use of the machine-gun was its use in aerial combat, both defensively against attacking opponents in the air and offensively against enemy airplanes and ground targets. At the same time their use from the ground against low-flying airplanes was being developed and strenuous efforts were made to improve their effectiveness when used either from the ground or in the air against aerial targets.

Tracer and Incendiary Bullets

To make the aiming of the machine-guns used against such targets easier and more certain, the expedient was adopted of using a hollow bullet containing a chemical mixture that is ignited by the powder charge in the cartridge when the machine-gun is fired and burns during the flight of the bullet with a bright light. By loading the belts or magazines so that every fifth or sixth cartridge is one having a tracer bullet, it is possible for the gunner actually to see the path of the bullet and quickly to direct his gun so that hits will be registered on the target. At the same time that this tracer ammunition was being developed for war use, the inflammable nature of aircraft and of captive balloons used for observation purposes brought home the desirability of devising ways and means of setting them on fire. To meet this requirement, incendiary ammunition was developed. This ammunition consists simply of a hollow bullet filled with phosphorous that burns during the flight of the bullet, and will set fire to inflammable material with which it may come into contact.

The small caliber of all machine-guns used up to this time limited the effectiveness of these special types of ammunition very materially, but the French had a cartridge 11 mm. (0.433-in.) in caliber that had been developed in 1874 for use in the French rifle of that caliber, and an investigation indicated that Vickers machine-guns of British and American calibers (0.303 and 0.300 in.) could easily be changed so as to fire this cartridge. The bullet of this cartridge is approximately 50 per cent greater in diameter than the bullet of the 0.303 and 0.300 cartridges, which made possible the design of a more effective incendiary bullet. This, accordingly, led to the development and use of the 11-mm. (0.433-in.) machine-gun, greater in caliber than any theretofore in general use in the war.

Several months after active work was begun on the 0.50-caliber machine-gun, a new cartridge designed and used by the Germans made its appearance on the western front. This cartridge had a bullet approximately ½ in. in caliber, and was used in combating tanks that carried considerable armor. The weapon from which the cartridge was fired is a single-shot rifle, in every way similar to the Mauser rifle with which the German infantrymen were armed, but of necessity larger in every respect. The ammunition, as designed, was very well thought out, and tests indicated that it would penetrate approximately 1 in. of good armorplate. The bullet was streamline in form and weighed 51.4 drams. A thorough investigation of this German cartridge made it desirable to redesign the 0.50-caliber cartridge previously developed by us, in order that our ammunition might at least be the equal of any other ammunition known. This resulted in a much more powerful cartridge, which in turn made necessary a slightly heavier gun. The complete 0.50-caliber cartridge weighs approximately 1890 grains. It is loaded with approximately 235 grains of powder, and its bullet weighs 804 grains. It takes about 23 0.30-caliber cartridges to weigh 1 lb. and only four 0.50 caliber cartridges. In other words, the 0.50-caliber cartridge is six times as heavy as the service cartridge. As soon as the design of the improved type of cartridge had been determined upon, a definite and specific program for the completion of the development of the machine-gun itself was laid down. This involved the design and manufacture of a limited number of each of three distinct types of gun; namely, the water-cooled type for use on the ground against ground targets, the anti-aircraft-tank type for use on the ground against aircraft and for mounting in tanks and the aircraft type for mounting in airplanes for use against ground targets or enemy aircraft. The design of these three has been carried along together and an endeavor made to have as many parts as possible common to all types. Samples of all three have been delivered and tested, and preliminary trials indicate that the program has been a success in every way.

The Browning 0.50-caliber machine-gun as finally perfected is a recoil-operated weapon, is belt-fed and fires at the rate of approximately 550 shots per min. Its operating principle is the same as that of the 0.30-caliber Browning machine-gun. The water-cooled gun weighs approximately 66 lb. without water and 82 lb. with the water-jacket filled. The water-jacket has a capacity of 8 qt. and the water reaches the boiling-point after 300 rounds of continuous firing. The gun is mounted on a tripod that weighs 80 lb. When fired, the gun imparts a muzzle-velocity of 2500 ft. per sec. to the 804-grain bullet and its maximum range is 9000 yd. Fig. 1 gives a graphic comparison of the trajectories of the 0.50-caliber bullet fired from the water-cooled machine-gun and the ordinary 0.30-caliber 150-grain bullet in regular use in our service.

The high state of development and the efficiency of this weapon, as well as the complexity of the design problems are obvious. The Browning anti-aircraft 0.50-caliber machine-gun develops 204 hp., or 1 hp. per 0.255 lb. The Browning 0.50-caliber water-cooled machine-gun develops the same horsepower, or 1 hp. per 0.294 lb. of weight. Weight for weight, the Browning 0.50-caliber water-cooled machine-gun develops more than 15 times the energy of the Liberty engine.

The field of usefulness of this weapon is very large, but probably the most important of all is its use from the ground against aerial targets, that is, for anti-aircraft defense purposes, and in view of recent tests that

demonstrate the enormous destructive power of bombs dropped from aircraft, it might be well to draw particular attention to its possibilities in this connection. This weapon is capable of projecting bullets into the air, each weighing 1/9 lb., at the rate of 550 to 600 per min. or 10 per sec. The initial velocity is such that the effective range against aerial targets is estimated to be at least 1500 yd. and one hit on a vital part of an airplane at this range will be disastrous. This means that in maneuvers, such as bombing, directed against objects on the ground that are properly protected by these guns, it will be necessary for an airplane to fly above this altitude to keep out of range, and this in turn means much less effective work. On account of its rapidity of fire and its high velocity, it is confidently believed that this weapon is by far the most effective weapon that has been developed to date for use from the ground against attacking airplanes.—Col. Herbert O'Leary in *Army Ordnance.*

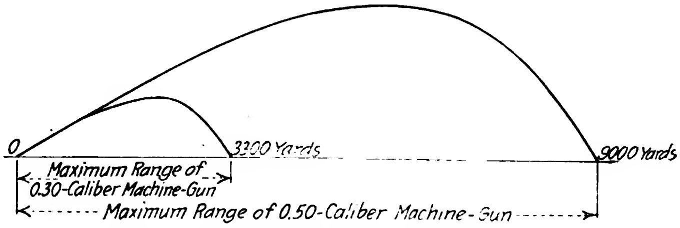


FIG. 1—DIAGRAMMATIC COMPARISON OF THE TRAJECTORIES OF THE 0.30 AND 0.50-CALIBER BROWNING MACHINE-GUNS

CHICAGO AND MINNEAPOLIS MEETINGS

(*Concluded from page* 170)

much lower than those in the foreign countries I have named, but they have been increased over 100 per cent and are now higher than those of our competitors. We have had also the advantage of better and more economical facilities for handling the grain in the country and at terminals, but a great change is taking place in this respect. As fine terminals as can be found anywhere in the world have been completed recently in Buenos Aires. Lines of country elevators similar to our own are to follow. Terminals and country elevators are being constructed in South Africa, promoted and financed by British capital, to take care of the increasing production of grain in that country.

I believe that the railroads will never be able to make a rate on grain from the Middle West to the sea that will enable us to maintain our place in the world's market. We must have deep-water transportation from our Great Lakes ports to the ocean, and we should have it without unnecessary delay.

LACK OF IMPROVEMENT IN RAILROADING

During the past 20 years nearly every kind of industry has undergone tremendous changes, to keep abreast of the times. Has any one observed any particular change in railroad methods, or any new development in rail transportation, during that period? To my knowledge, there has not been a single improvement of any kind or a single change in method in railroading for more than 20 years. The railroad people say that their hands have been tied by the Government on the one side and by the Labor Board on the other, but I have never known of any railroad management of recent years taking the initiative in anything that would improve rail transportation.

The function of the Interstate Commerce Commission should be modified, the railroads being permitted to make rates subject to review by the Commission only in case of general complaint. This is the way in which the Commission worked for many years after it was created. The result was more satisfactory to the railroads and to the public than that had under the present method. The whole responsibility of management and operation should be on the railroad executives.

I quote from a recent bulletin of the *American Exporter:* "Bad as our export trade seemed during the past year, it was greater in both value and volume than in any prewar year. For the 10 months ending October 1921 our exports were 94 per cent greater than in the same period of 1913."

Our basic industry, agriculture, has started on the road to recovery, and the prospect for profits in farm operations is good. With the present prices of farm labor and implements and all that the farmer has to buy, I have never seen better chances for agriculture. The farmer who cannot make money under present conditions is not capable.

I believe that motorization of the farm has only started. A properly planned and intelligently operated motorized farm possesses decided economic advantages over the farm operated by draft animals, besides doing away with a large percentage of the drudgery that drives so many of the boys from the farm. It is pretty difficult to keep the boy on the farm driving horses. He feels when night comes that he has not accomplished much, and he has a half-day's work to do after he quits the field. With his tractor he feels that he has accomplished something. It is the psychology of the thing that will put power farming over in spite of all anybody can say regarding it. It has such a start that nothing under heaven can stop it.

I believe that there is room for improvement in the machines that are being supplied. You engineers can design and make machines that are more adaptable than those that are now on the market. More attention should be paid to the accessibility of the machine, and to simplicity of operation and handling, particularly the latter. Many of the machines that are out are mighty awkward machines. The manufacturers must recognize the responsibility that goes with the sale of machines. I think they have not always done that. They have sold machines in territories where they had to go many miles from the railroad station, with little regard to the requisites of service or to having spare parts available. Too many sales are made with little consideration as to the machine sold being suitable for the work in prospect. Considering the conditions under which he has labored, the progress the farmer has made in the use of power implements is wonderful. Some people harp on the inability of the farmer to operate the machines. I believe that no class that would take the kind of tractors that have been put out would make any greater success in the operation of them than the farmers have made. To me the most phenomenal thing about the whole situation is that so few of them fail with their tractors. Some records I gathered last year show that over 86 per cent of about 800 farmers who had been interviewed were operating their machines satisfactorily. Most of the other 14 per cent were not well pleased with their purchases but thought they had some advantages. Only 3 or 4 per cent condemned the machine. I think that is a remarkable record. I think that with the return of prosperity to agriculture that is sure to come sooner

or later we can look forward to a constantly increasing use of power implements.

Past-President Beecroft, in extending the thanks and salutations of the Society to the Minneapolis Section, the speakers and the guests, called attention to the fact that the members are studying current problems from the standpoint of economics, and are not bound up in the four walls of their laboratories. He said that the paramount duty incumbent upon engineers today is to get out into the field and study the conditions there. He continued:

We should eliminate the word "pessimism" from our vocabulary in these days. It is abused. So is the word "optimism." Man can never attain the stature for which he was intended if he is always placed in beds of roses and lives in days of expansion and optimism. These are the grandest days that were ever lived. Who would want to live in this world if we had say 40 years like 1918, 1919 and 1920? These may be mentrying days, nerve-trying days, but surely they are not pessimistic days. They are days when we must get out and study the problems first-hand.

The automobile, the truck, the tractor and the airplane are prime essentials of civilization today. It is said that we must have, first, food, then shelter; then, clothing. But what is it that knits all of these together? It is transportation. It has been made plain here tonight that one of our great problems consists of the evils that have been tied around transportation as we know it today. I think that those great arterial aspects of transportation, the truck and the tractor, will be able in great measure to solve the situation. But we must look upon them sanely.

I have no patience with those people who want to call the automobile in any of its useful fields, such as those connected with farming and many other phases of life, a luxury; it does not exist as that; it is one of the great essentials of life. In these days let us be sure that we look at the matter in that light. Who would want to live on the farm without modern means of transportation?

ESSENTIALS OF FARM LIFE

Mr. Record referred to the Argentine. I had the opportunity of crossing that country in 1916. One of the saddest memories of my life is agricultural Argentina. In that huge expanse of territory the country people are a century behind the city people. I have no sympathy with those who want to keep anything agricultural behind the times. The agricultural people of this Country must walk side-by-side with the city people. We want them to have automobiles. We want them to have motor trucks when they are used economically. We insist that they have tractors when they are applied successfully and used economically. We want them to have the other things that make life a pleasure, that make life on the farm as comfortable as it is in the city. Only when we have life on the farm as it is in the city will we in this Country speak as a united people, as a homogeneous people, which we want to be.

Our Society is doing and has done a great work, and will continue to be a worthwhile Society only in proportion to the character of the work it does. We as a people, we as an industry, we as a Society will be remembered by the character of our work, by the spirit that we put into it, by the sacrifice that we make in our every act.

In these days the one thing we must do is to dedicate ourselves to the work of readjustment. During the war the Allies settled down to the business of war. In 1915 and 1916 we could not understand how they were getting along, but to them it was perfectly natural; they said, "Our business is war and we are carrying it on." Is not our business now readjustment? Let us hold high the torch of personal sacrifice, that torch of service. If we, as a united Society, as a united industry, as a united people, keep that ideal before us, we shall succeed.

SPECTROSCOPIC INVESTIGATION OF INTERNAL COMBUSTION

(*Concluded from page* 219)

ates a very sensitive galvanometer, and the wave-length corresponding to the maximum deflection on the galvanometer gives a means of calculating the absolute temperature existent at that time. By again using a stroboscope to regulate the time for the readings, we believe it possible to derive temperature-time cards of the power stroke.

The chemical changes occurring during combustion can be investigated by the bands in the spectrum due to carbon monoxide, carbon dioxide, water vapor and the like. Each compound has its characteristic spectrum, and the successive appearance and disappearance of these lines should yield valuable information on the nature of the combustion. This is, perhaps, the most difficult of the three problems, because these lines are very faint; in fact, they are so faint that we have observed any one of them only a few times, and we do not seem to be able to duplicate them. However, the behavior of the continuous spectrum from this standpoint is interesting for the reason that it tells us a great deal about how the free carbon behaves during combustion.

The study of the combustion of compressed mixtures of gasoline and air as it occurs in engines is in its infancy. The knowledge that we now have on this fundamental process is very limited, and many of the ideas that are held in regard to combustion are necessarily of a hypothetical nature. For the accurate study of the nature of combustion, which is a chemical reaction that occurs very rapidly and at high temperatures, instrumentation is necessary. In this connection the spectroscope offers great promise as a means of investigating the character of combustion reactions in internal-combustion engines.

FIG. 5—PHOTOGRAPH OF A STROBOSCOPIC SPECTRUM OF THE LIGHT COMING FROM AN INTERNAL-COMBUSTION ENGINE CYLINDER WHERE A VERY HIGH PRESSURE EXISTED FOR A THIRD OF THE COMBUSTION STROKE

ACTIVITIES OF THE SECTIONS

Secretaries of the Sections

BUFFALO SECTION—C. A. Criqui, chairman, Sterling Engine Co., Buffalo
CLEVELAND SECTION—E. W. Weaver, 5103 Euclid Avenue, Cleveland
DAYTON SECTION—R. B. May, Dayton Engineering Laboratories Co., Dayton, Ohio
DETROIT SECTION—B. Brede, assistant secretary, 1361 Book Building, Detroit
INDIANA SECTION—B. F. Kelly, Weidely Motors Co., Indianapolis
METROPOLITAN SECTION—F. E. McKone, 347 Madison Avenue, New York City
MID-WEST SECTION—T. Milton, 140 South Dearborn Street, Chicago
MINNEAPOLIS SECTION—C. T. Stevens, Reinhard Brothers Co., Minneapolis
NEW ENGLAND SECTION—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston
PENNSYLVANIA SECTION—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
WASHINGTON SECTION—B. R. Newcomb, 211 Victor Building, City of Washington

PROF. H. B. LEMON, of the University of Chicago, addressed the Mid-West Section on Feb. 3 on the subject of The Nature of Matter. Many of the very illuminating points he made were demonstrated by an unusually interesting series of laboratory experiments. The meeting was attended by several of the officers of the Society who were in Chicago in connection with the meeting of the Society held there earlier in the week. The large enthusiastic audience was given a great treat by being taken on a tour of inspection through several of the University laboratory departments. It is believed that the meeting inaugurated a helpful program of cooperation between the University and the Society.

The Metropolitan Section assisted the Society in the conduct of the Motorboat Meeting held at the Hotel Commodore, New York City, on the morning of Feb. 21. Com. Ernest Nibbs, formerly of the British Navy, gave a paper on The Development and Building of Diesel Engines and spoke of the fuel-saving possibilities of heavy-oil engines as compared with those using lighter fuels. R. B. Lea spoke of Compound Oil Engines for Marine Use, his talk being illustrated by lantern slides. Albert Hickman gave a sparkling address on Surface Propulsion in general and with particular reference to its use with the sea-sled type of hull. These papers, with the discussion which followed, completely filled the morning. Joseph VanBlerck presided at the meeting.

Following the technical session a luncheon was held at which William Washburn Nutting acted as toastmaster. Those who heard Nutting's account of his Transatlantic trip in the Typhoon at the Motorboat Dinner last year were not disappointed in his lively remarks at the luncheon. Dr. Walter E. Traprock, famous as the author of The Cruise of the Kawa, entertained the members and their guests with a narrative of his experiences while cruising in the South Seas.

Members of the New England Section who were not fortunate enough to be able to be on hand at the Motorboat Meeting in New York City were nevertheless able to attend a similar session in Boston on Feb. 24, when N. Warshaw presented a paper on Marine Engines. The meeting was preceded by a dinner at the Engineers' Club.

Increasing attention is being paid by the Sections to current economic conditions. The Pennsylvania Section on Feb. 23 listened to two most interesting speakers, Col. John Price Jackson, consulting engineer, at present retained by the Industrial Relations Committee of the Philadelphia Chamber of Commerce, who talked on What We May Expect in the Near Future in the Light of Today's Industrial Conditions and Basic Price-Movements, and E. J. Cattell, city statistician, who brought forth some new facts and figures and reasons for optimism regarding the future. In both of these talks consideration was given to the status of the automotive industry in the general situation and suggestions were made as to the part which the engineer should play in industrial betterment.

Schedule of Sections Meetings

MARCH

1—MINNEAPOLIS SECTION—Development in Automotive Transportation and Equipment—A. W. Scarratt

7—DAYTON SECTION — Some Aspects of Air-Cooled Cylinder Design and Development—S. D. Heron

17—NEW ENGLAND SECTION—Business Aspects of the Automotive Industry—H. W. Parlin.

21—BUFFALO SECTION—Electric Wiring Systems—W. S. Haggott

23—METROPOLITAN SECTION—Truck Rear-Axles—Ethelbert Favary

23—PENNSYLVANIA SECTION—Batteries and Electrical Equipment. Also paper by J. M. Teasdale

24—DETROIT SECTION

31—MID-WEST SECTION — Various Commercial Fuels and Their Relative Characteristics

APRIL

5—MINNEAPOLIS SECTION—Tractor Publicity and Demonstrations

21—METROPOLITAN SECTION - NEW ENGLAND SECTION—Joint meeting at New Haven, Conn. Inspection of laboratory equipment; and description of methods used in determining losses from the engine to the road, by Prof. E. H. Lockwood

21—DETROIT SECTION—Crankcase Dilution

27—PENNSYLVANIA SECTION—Commercial Motor Transportation

28—MID-WEST SECTION—Fundamental Losses in Automotive Apparatus

The Minneapolis Section arranged the excellent session held on Feb. 8 at which highway matters and the use of tractors in the building and maintenance of roads were discussed. It was also of invaluable assistance in the holding of the Society technical session and the dinner in Minneapolis on Feb. 9.

Coming Meetings

At the Dayton Section Meeting which will be held on March 7, S. D. Heron will present a paper on Air-Cooled Cylinder Design and Development. This paper is a very complete presentation of the subject, and is, in the opinion of a number of those who have seen the manuscript, one of the best papers ever given to members of the Society. The presentation of this paper at the March meeting of the Dayton Section is particularly fortunate since it will enable a number of the Society's officers who will attend the Council Meeting on that date to be present.

W. S. Haggott has in preparation a paper on Electric Wiring Systems, which he will give before the Buffalo Section on March 21. It is believed that this paper may possibly be used as a basis for standardization work along these lines, and members of the Electrical Equipment Division of the Standards Committee are particularly urged to attend.

CURRENT STANDARDIZATION WORK

Letter ballots on adoption of the standards recommendations approved by the Standards Committee, the Council and the Society in annual meeting were sent to the voting members of the Society early in February. As these ballots will be counted on March 11, members should see that they reach the Society prior to that date.

The next issue of data sheets, which will contain the recommendations approved at the Annual Meeting, will be mailed to the members early in March. This issue will contain over 200 pages, the largest single issue representing current standardization work that has ever been sent to the members. The Iron and Steel Report covers 73 pages. Copies of this report will be available also in booklet form.

Members should see that the new issue of data sheets is correctly inserted in their S. A. E. Handbooks so that they may be sure they have at hand the most recent revisions of all the S. A. E. Standards. An incident recently came to the attention of the office of the Society in which a bid was solicited on a quantity of material conforming to a certain S. A. E. Specification. The bid submitted was much lower than expected owing to the fact that it had been based on an obsolete copy of the specification covering that material.

The letter from the Society that will accompany the March issue of data sheets will contain a check-list of S. A. E. Handbook data sheets. This will enable the members to check their S. A. E. Handbooks so that they will be sure that they have all, as well as the most recent, data sheets issued to date.

The new issue of data sheets will bring the total number of pages in the S. A. E. Handbook to 468. When it is appreciated that the standards as published by the Society are limited to the definite recommendations, no historical or explanatory matter being included, the large amount of work that the standards represent will be understood.

Information has been submitted to the members of each Division giving the status of the several subjects which have been assigned to the Standards Committee, together with lists of the personnel of the Subdivisions which have been appointed. Data in reference to subjects awaiting the consideration of any of the various automotive or parts and materials Divisions of the Standards Committee will be sent to interested members upon request.

INDUSTRIAL UNEMPLOYMENT

It is estimated that, in 1920, the total number of persons engaged in gainful occupations in the United States was about 41,000,000. Most of the available employment statistics pertain to wage-earners in the groups of manufacturing and mechanical industries, which numbered, in 1920, about 12,800,000. During normal times, it is estimated, about 1,800,000 of these are out of work, since on the average about 42 days per year, or about 14 per cent of his total working time, is lost by each industrial wage-earner. The workers in many industries are subject to longer periods of unemployment, while in others the average is low. The unemployment situation has been abnormal due to business depression. It is estimated that over one-quarter of the industrial wage-earners were out of work on June 1, 1921, representing an estimated total of 3,500,000 persons.

There is need for a more adequate system of collecting and disseminating information showing the trend of prices, the actual cost of operation and the revenues from industry. Such a system will afford a reliable basis of comparison within plants at different times and between individual plants in the industry as a whole. The application of such methods to all industries will provide a kind of clinical thermometer of industry, which will afford a more trustworthy guide for judging future needs and prospects in the industrial system. The more the future situation can be anticipated, the more will it be possible to establish bases of control over normal production, distribution and consumption and over the fluctuations from prosperity to depression that recur at varying intervals of time.—From a report of National Industrial Conference Board.

PRODUCTION ORGANIZATION

There are two features that characterize all the systems of works records that really give satisfaction. In the first place they provide definite information on all matters upon which information is essential to the management, and they will also be found to have been developed in the particular establishment in which they are in force. These characteristics alone are sufficient to indicate the course to be adopted in any works in which it is felt that an existing system is inadequate or has outlived its usefulness. Instead of deciding to import somebody else's method, with the almost certain result of causing administrative indigestion throughout the factory, it is better for the manager to determine deliberately for himself, what are the exact questions upon which he wishes information to be available. It is a sound general rule that no fact is worth recording unless it may be useful as the basis of some executive act, either then or in the future. To acquire knowledge for its own sake is commendable in certain circumstances, but useless facts are worse than superfluous in the records of a firm. They involve time and expense in their collection, and discredit the system by smothering the wheat with valueless chaff. The decision as to what are the essential facts to be recorded is not one to be taken hastily, and the conclusion is likely to be different in different factories. When once it is made, there is established the beginning of a sound system of records which by reason of its simplicity and direct usefulness will be easily and sympathetically maintained by those upon whom its functioning depends.—*Engineering* (London).

S. A. E. Standards Exhibit at the Minneapolis Tractor Show

THE fifth annual exhibit of the Society at the National Tractor Show and Demonstration, held at Minneapolis during the week of Feb. 6 to 11, was of unusual interest and educational value. It consisted in part of large posters, making plain the current use of S. A. E. Standards in tractor construction, and specifying the standards that have been applied in the building of automotive engines and motor trucks. Two charts showed graphically and in figures the wholesale value of motor trucks and passenger cars produced in 1921, the saving attributed to the use of S. A. E. Standards in their production, and the cost of formulating S. A. E. Standards in 1921.

Statistics that are considered reliable indicate this wholesale value to be $1,222,350,000, or 22,224 times the cost in 1921 of formulating S. A. E. Standards. The saving due to the use of the standards, based on an average of estimates made by nearly 150 prominent engineers and executives, amounted to 15 per cent, that is, $215,135,000, or 3911 times the cost of the 1921 standardization work. The estimated direct total cost of the Society's standardization activity during 1921 is $55,000.

The accompanying chart showing the respective percentage of tractor producers using various S. A. E. Standards is based on replies to a questionnaire sent to more than 100 companies in January.

A feature of the exhibit was six cartoons emphasizing practical reasons for and advantages of the reduction to practice of S. A. E. Standards as assisting directors of companies in planning production and helping a customer in difficulty, a car-owner in trouble, the dealer in stocking parts, the factory inspector in checking purchased parts and the tool and general production departments in reducing costs and equipment.

An important part of the exhibit consisted of more than 50 selected groups of different automotive parts, each a strictly commercial article, illustrating in concrete form the application of the standards in practice. These were arranged on long tables along the sides of the booth, and accompanied by the corresponding data sheets from the S. A. E. HANDBOOK.

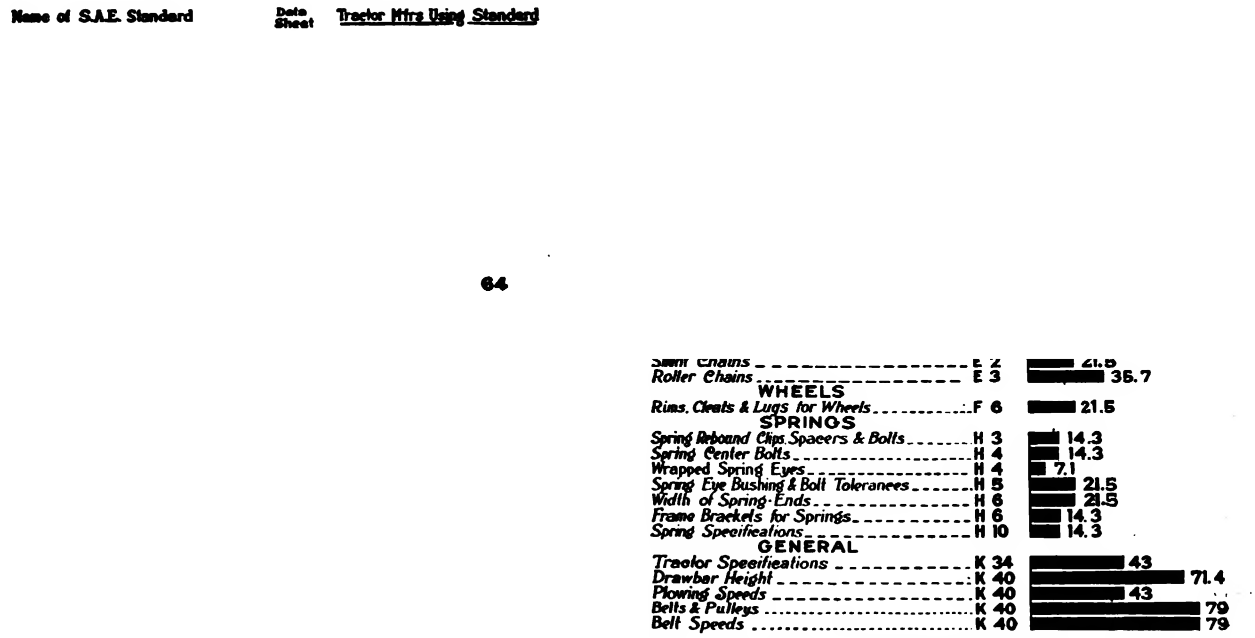


CHART SHOWING THE RELATIVE NUMBER OF TRACTOR BUILDERS USING THE 70 S. A. E. STANDARDS APPLICABLE TO TRACTOR CONSTRUCTION

The simple but thoroughly convincing nature of the exhibit was amply demonstrated by the interest shown by the large number of visitors, many of whom were agriculturists who had not previously known of the S. A. E. Standards. A number of these expressed the intention of talking with their local dealers regarding the desirability of incorporating as many of the standards as possible in the products they handle. Much information was disseminated in relation to the scope and work of the society, as well as its membership and several publications.

The Show afforded an excellent opportunity to obtain at first hand an insight into the rapidly growing appreciation on the part of builders and users of tractors and agricultural power-driven implements of the essential value of practical standardization and of the fundamentally important work the society is carrying forward through its widespread membership and the automotive industries in general.

DISTRIBUTION OF INCOME FROM PRODUCTION

CALCULATED in dollars the national income increased from $31,300,000,000 in 1910 to $66,000,000,000 in 1919, but calculating the value of the national product at 1913 prices the figures for 1919 are only $37,300,000,000, showing that the actual gain in product was only about 20 per cent, which is not much more than normal growth for 9 years. The figures for each of the years are as follows:

Year	National Income, billions of dollars	Weighted Index Number of Prices	Purchasing Power at Price Level of 1913, billions of dollars
1910	31.1	97.8	31.8
1911	31.2	98.5	31.6
1912	32.4	99.4	32.6
1913	33.3	100.0	33.3
1914	32.5	100.6	32.3
1915	35.9	102.5	35.0
1916	45.5	113.4	40.1
1917	53.9	136.1	39.6
1918	61.7	160.8	38.4
1919	66.0	176.8	37.3

The final estimate of the average income per capita and purchasing power at the price level of 1913, for the years from 1909 to 1918, is as follows:

Year	Population, millions	National Income, billions of dollars	Income Per Capita Income, dollars	Purchasing Power at Price Level of 1913, Income, billions of dollars	Per Capita Income, dollars
1909	90.37	28.8	319	30.1	333
1910	92.23	31.4	341	32.2	349
1911	93.81	31.2	333	31.7	338
1912	95.34	33.0	346	33.2	348
1913	97.28	34.4	354	34.4	354
1914	99.19	33.2	335	33.0	333
1915	100.43	36.0	358	35.2	350
1916	101.72	45.4	446	40.7	400
1917	103.06	53.9	523	40.8	396
1918	104.18	61.0	586	38.8	372

One of the most interesting results shows the division of combined net-value product of mines, factories and land transportation between earnings of employes and returns for management and the use of property. The figures are given in millions of dollars and also in percentages of the net value of the product, as follows:

Year	Wages and Salaries (millions of dollars)	Management and Property (millions of dollars)	Wages and Salaries (per cent)	Management and Property (per cent)
1909	6,481	2,950	68.7	31.3
1910	7,156	3,250	68.8	31.2
1911	7,287	2,791	72.3	27.7
1912	7,993	3,169	71.6	28.4
1913	8,651	3,359	72.0	28.0
1914	7,947	2,816	73.8	26.2
1915	8,722	3,470	71.5	28.5
1916	11,630	5,810	66.7	33.3
1917	14,375	6,502	68.9	31.1
1918	17,472	5,124	77.3	22.7

The lesson to be found in this study of incomes is that they are governed by economic law, and not, as commonly assumed, by arbitrary power. They are not, in any general sense, within the control of employers, either singly or as a body, to fix as they please; nor can the general wage-level be materially changed by organization among wage-earners. There are certain relationships throughout industry, between the amounts disbursed for wages, required additions to capital, the share of the industrial product that shall be in the form of goods for current consumption and the share that shall be in the form of productive equipment, which in the long run are bound to be maintained. There is a balance, or equilibrium, in industry which must be maintained for the best interests of all; if it is disturbed, the normal exchange of goods and services is interrupted, and although wages may be nominally high they are actually low when taken into account. The latter is the state of things existing today not only in this country, but also throughout the entire world.

Wages must be high enough to enable the wage-earning class to buy and consume their normal share of the industrial product; otherwise products will accumulate and business will be bad. Likewise, farm products must have a purchasing power compared with other things that will allow the great body of people who live on the farms to take their usual share of goods, or unemployment in the other industries will result. Thus, every class, instead of being interested in fixing its own compensation without regard to the effect upon others, is interested in that right adjustment of values which enables the exchanges to be completely made, and in that manner serves the common interest.—National City Bank of New York.

HIGHWAY TRANSPORTATION AND THE AUTOMOTIVE ENGINEER

(*Concluded from page* 217)

hillsides. In Virginia a concrete road was built that held all right until the water got beneath it, which ruined the sub-grade and the road. It is worse than it was formerly, because the road is standing on edge.

MR. TEMPLIN:—It is no doubt true that the sub-grade has an important bearing on the success of the road. I do not wish to convey the idea that impact is the only destructive factor, because a defective sub-grade is another very important factor in road construction.

CHAIRMAN SMITH:—The Goodyear company has taken a broad-gage view of the situation; it makes tires and practically everything in the rubber line. Theoretically, it ought not to make much difference to the company what kind of tires it makes, but it is doing research work that is really worth while. We know that a bicycle weighing about 50 lb. will carry a load of 150 lb.; that a motorcycle weighing 150 lb. will carry 150 lb.; that a touring car is very poorly off in that a 4000-lb. car is designed to carry only about 300 lb.; and that a standard truck weighs approximately the same as its nominal pay-load. The Goodyear company has succeeded in producing a truck that carries a high ratio of pay-load to its weight and has been able to increase the operating speed. Speed is a commercial factor, always; in fact, it is a condition.

It is a pleasure to ride for 24 hr. on one of those six-wheel trucks and I have done this in a truck equipped with 12-in. tires with less fatigue than I have felt in some touring cars after a 10-hr. drive.

Applicants *for* Membership

The applications for membership received between Jan. 23 and Feb. 16, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, ROBERT A., general manager, Victory Hammered Piston Ring Co., *Newark, N. J.*

ANSCHUETZ, HARRY GEORGE, sales manager, Paul M. Marko & Co., *Brooklyn, N. Y.*

BEAUCHAMP, STAFFORD DUPONT, student, Georgia School of Technology, *Atlanta, Ga.*

BERRY, JOHN T., superintendent, Carriage Factories, Ltd., *Orillia, Ont., Canada.*

BILLMAN, H. C., instructor automobile mechanics, National Military Home, *Dayton, Ohio.*

BISHOP, WALTER W., JR., test engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

BLOMBERG, M., motor truck engineer, National Steel Car Corporation, *Hamilton, Ont., Canada.*

BORDEN, EDWARD ROY, mechanical engineer, Mudge & Co., *Chicago.*

BOUSE, MUREL R., instructor, Chanute Field, *Rantoul, Ill.*

BRAY, GEORGE H., assistant to supervisor of equipment, Texas Co., *Boston.*

BROOKS, HOWARD, assistant superintendent, American Smelters Securities Co., *Velardena, Mexico.*

BURLEY, HARRY B., president, Boston Insulated Wire & Cable Co., *Dorchester, Mass.*

CALDWELL, JESSE THOMAS, commercial engineer, National Lamp Works of General Electric Co., *Cleveland.*

CARSON, RAY EDGAR, student, Purdue University, *Lafayette, Ind.*

CASON, PAUL B., draftsman, Kimball Motor Truck Co., *Los Angeles, Cal.*

CHRISTIANSEN, SVEND A., test engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

CLARK, HAROLD EDMUND, motor-truck salesman, Packard Motor Car Co., *New York City.*

CLINE, N. N., student, Purdue University, *Lafayette, Ind.*

CRABILL, P. P., president and engineer, Central Brass & Fixture Co., *Springfield, Ohio.*

CROWELL, WILLIAM S., instructor, Y. M. C. A. Automobile School, *San Francisco.*

DALE, E. B., assistant professor of automotive mechanics, Colorado State Agricultural College, *Fort Collins, Col.*

DAVIS, FRED, engineering tests, General Motors Research Corporation, *Dayton, Ohio.*

DONAHEW, A. L., student, Purdue University, *Lafayette, Ind.*

EBERTS, JOHN FOSTER, student, Purdue University, *Lafayette, Ind.*

EYERLY, L. U., automotive engineer, 246 State Street, *Salem, Ore.*

FAUNTLEROY, HERMANZE EDWIN, student, Purdue University, *Lafayette, Ind.*

FAY, CHARLES R., student, Purdue University, *Lafayette, Ind.*

FIELD, BURNHAM E., metallurgical engineer, Union Carbide & Carbon Research Laboratories, Inc., *Long Island City, N. Y.*

FITZGERALD, EVERETT, Adirondack Power & Light Corporation, *Amsterdam, N. Y.*

GARDNER, ARCHIBALD D., student, graduate school of engineering, University of Michigan, *Ann Arbor, Mich.*

GRABNER, JOHN, student, Purdue University, *Lafayette, Ind.*

GRAPE, THEODORE S., manager and proprietor, Bearings Sales Co., *City of Washington.*

GRISELL, LOWELL HOBART, student, Purdue University, *Lafayette, Ind.*

HANNAH, WALTER JOHN, consulting engineer, Hannah King & Co., *Glasgow, Scotland.*

HARRIS, ELMER P., proprietor, Harris Mfg. Co., *New York City.*

HAZEN, RONALD MCKEAN, student, University of Michigan, *Ann Arbor, Mich.*

HEATON, HOWARD H., student, Purdue University, *Lafayette, Ind.*

HOLMES, H. GLENN, chief engineer, Novo Engine Co., *Lansing, Mich.*

HOYNE, BLANCHARD H., student, Purdue University, *Lafayette, Ind.*

HUBBARD, LEWIS EDWARD, student, Purdue University, *Lafayette, Ind.*

HUGHES, F. J., technical representative, Tilling-Stevens Motors, Ltd., *Maidstone, England.*

JOHNSON, E. F., general manager parts division, General Motors Corporation, *Detroit, Mich.*

KAPLAN, SIMON, sales manager, 1419 North Charles Street, *Baltimore, Md.*

KIRBY, MAJOR MAXWELL, Air Service, *City of Washington.*

MAGGS, ALBERT H., designing engineer, Ahrens Fox Fire Engine Co., *Cincinnati.*

MANN, ERNEST W., assistant engineer, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*

METZROTH, WILLIAM, factory manager, Dyneto Electric Corporation, *Syracuse, N. Y.*

MILLER, ALBERT H., research engineer, Midvale Steel & Ordnance Co., *Philadelphia.*

MORTON, JENKINS JESSE, student, Purdue University, *Lafayette, Ind.*

PROVOOST, WILLIAM REES, draftsman, Tietjen & Lang Co., *Hoboken, N. J.*

PUHEK, MATT J., specification clerk, Dort Motor Car Co., *Flint, Mich.*

RAMSDALE, FRED, student, Pratt Institute, *Brooklyn, N. Y.*

RITZI, HARRY, student, Purdue University, *Lafayette, Ind.*

SCHAD, ALFRED BARTH, student, Purdue University, *Lafayette, Ind.*

SCHAKEL, RAYMOND ANTON, student, Purdue University, *Lafayette, Ind.*

SELLARDS, FRANK BOLTON, student, Kansas State University, *Lawrence, Kan.*

SOLBRIG, H. E., student, Purdue University, *Lafayette, Ind.*

SPRINGER, RUSSELL S., vice-president and factory manager, Holt Mfg. Co., *Stockton, Cal.*

STEEN, ADOLPH F., student, Purdue University, *Lafayette, Ind.*

STEPHENS, GEORGE H., chief engineer, Fansteel Products Co., Inc., *North Chicago, Ill.*

SWEET, WILLIAM M., vice-president, Klaxon Co., *Bloomfield, N. J.*

TAYLOR, JAMES RUSSEL, student, Purdue University, *Lafayette, Ind.*

TEETOR, IVAN, mechanic, General Motors Research Corporation, *Dayton, Ohio.*

THOMAS, THEODORE PAUL, student, Purdue University, *Lafayette, Ind.*

TODD, W. E. ARTHUR, Beaver Truck Corporation, Ltd., *Hamilton, Ont., Canada.*

TOLPUTT, HERBERT, manufacturer, Tolputt Co., *Sheffield, England.*

TUFFORD, HENRY HORACE, manager of tire instruction and supervisor of tire department, Dunwoody Institute, *Minneapolis.*

TUTTLE, J. H., chief engineer, Westcott Motor Car Co., *Springfield, Ohio.*

VAN ZANDT, FIRST-LIEUT. J. PARKER, Air Service, McCook Field, *Dayton, Ohio.*

WAINWRIGHT, J. DANIEL, Southern sales director, 643 Carondelet Street, *New Orleans, La.*

WENDELL, EVERT J., chief engineer and manager, Hale Fire Pump Co., Inc., *Conshohocken, Pa.*

WHITE, HERBERT R., general sales manager, Lancaster Steel Products Corporation, *Lancaster, Pa.*

WILFORD, J. W., general manager, General Products Co., *Detroit.*

WILLIAMS, GORDON HUNTER, student, Columbia University, *New York City.*

WILLIAMS, JOHN LEACH, assistant production manager, Canadian Products, *Walkerville, Ont., Canada.*

WILLIAMS, R. A., assistant supervisor of motor equipment, Texas Co., *Norfolk, Va.*

WINKLER, WILLIAM, owner, Winkler Motor Service, *Chicago*.

WINNER, CARL S., mechanical draftsman, Rock Island Arsenal, *Rock Island, Ill.*

WOOD, R. M., student, Georgia School of Technology, *Atlanta, Ga.*

WOODS, LEONARD R., salesman, Dorris Motor Car Co., *St. Louis*.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ACKERMAN, PAUL C. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 327 Thompson Street.

AHLERS, MILTON THEODORE (A) assistant chief engineer, City Machine & Tool Works, *Dayton, Ohio*, (mail) 847 Bowen Street.

ALTHOUSE, ANDREW D. (M) instructor, Cass Technical High School, Detroit, (mail) R. F. D. 1, *Oxford, Mich.*

BENTON, EDWIN L. (J) service manager, Benton Electric Co., *LaCrosse, Wis.*, (mail) 112 North 10th Street.

BLACK, GEORGE A., JR. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 624 Packard Street.

BOLGIANO, JOHN F. (S M) chief draftsman, transportation branch, balloon and airship section, Air Service, McCook Field, *Dayton, Ohio*.

BOSWORTH, ALVAH H. (A) vice-president and chief designing engineer, Colador Engineering Corporation, *Long Island City, N. Y.*, (mail) 8601 89th Avenue.

BURGER, GEORGE EDWIN, JR. (E S) mechanical engineer, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 1 Walnut Grove Place.

BURSIK, FRANK JAMES (E S) student, Armour Institute of Technology, *Chicago*, (mail) 1443 South Central Park Avenue.

BUSHNELL, SHERMAN W. (A) automotive engineer, 2515 Fourth Avenue, *Seattle, Wash.*

CANAVAN, J. JEROME (A) transportation engineer, 619 Chapman Building, *Los Angeles, Cal.*

CARTER, THOMAS FREDERICK (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 55 West North Avenue.

CHILMAN, CAPT. H. LEA (J) commercial transport consultant, 50 Daisybank Road, Victoria Park, *Manchester, England*.

CLARKE, JAMES RUSSELL (A) president, American-LaFrance Fire Engine Co., Inc., Elmira, N. Y., (mail) 250 West 54th Street, *New York City*.

CLARKE, LOUIS E. (A) sales manager, bearing and die-casting department, Hoyt Metal Co., Boatmen's Bank Building, *St. Louis*.

DAYTON, JOHN C. (A) engineer and manager, Dayton Gas & Electric Engineering Works, *Harrisburg, Pa.*, (mail) 1927 Logan Street.

ECKMAN, NORMAN H. (A) vice-president and general manager, Center-Fed Spring Insert Sales Co., Coal Exchange Building, *Wilkes Barre, Pa.*

EMERSON, L. A. (M) head of automotive department, William Hood Dunwoody Industrial Institute, *Minneapolis*.

FRANCIS, C. K. (M) chief chemist and technical superintendent, Cosden & Co., 1415 South Elwood Avenue, *Tulsa, Okla.*

GAUTHIER, EDWARD (J) mechanical draftsman, Holt Mfg. Co., 444 South Aurora Street, *Stockton, Cal.*

GELPKE, ADOLPH (M) chief draftsman, Autocar Co., *Ardmore, Pa.*

GRABOW, FREDERICK C. (J) designer, Shaw-Enochs Tractor Co., *Minneapolis*, (mail) 4600 Pleasant Avenue, South.

HEDRICH, O. H., JR. (E S) student, University of Illinois, *Urbana, Ill.*, (mail) 1204 West Green Street.

HOPKINS, FRED J. (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 164 West North Avenue.

HURD, RALPH H. (M) engineer, Libby & Huls, *Chicago*, (mail) 1323 West 98th Street.

HAMILTON, ERWIN (M) instructor in mechanical engineering, New York University; instructor in automotive engineering, United Y.M.C.A. Schools, *New York City*, (mail) New York University, 181st Street and University Avenue.

JOHNSON, ANDREW F. (M) instructor, Correspondence School for Automobile Body-Makers, Designers and Draftsmen, *Gray, Me.*, (mail) Gray, Me.

JONSSON, JOHN ERIK (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 272 Hoosick Street.

KEIM, BYRON, L. (J) mechanical engineer, R. D. Nuttall & Automotive Parts Co., Pittsburgh, (mail) 1459 Foliage Street, *Wilkinsburg, Pa.*

KOELBLE, EDNA O'CONNOR (A) 370 Manhattan Avenue, *New York City*.

KOERBER, ARTHUR W. (M) draftsman, O. E. Szekely Engineering Co., Moline, Ill., (mail) 2831 Sixth Avenue, *Rock Island, Ill.*

LANGE, EDWARD C. (M) Pacific Power Implement Co., Foot of Jackson Street, *Oakland, Cal.*

LATHEM, JOSEPH GAULT, JR. (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 103 Ashby Street.

MALONE, D. G. (E S) student, University of Illinois, Urbana, Ill., (mail) 411 East Green Street, *Champaign, Ill.*

MESSINGER, CARL W. (A) sales representative, Stanley Works, New Britain, Conn., (mail) 1105 Kresge Building, *Detroit*.

MURPHY, JOHN EDMUND, 2ND (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 55 West North Avenue.

NEUHART, J. H. (A) general manager, Liggett Spring & Axle Co., *Monongahela, Pa.*

NOFSINGER, CHARLES W. (E S) student, University of Illinois, Urbana, Ill., (mail) 61 East Green Street, *Champaign, Ill.*

OHSAWA, GEN (E S) student, University of Illinois, Urbana, Ill., (mail) P. O. Box 525, *Champaign, Ill.*

PACKER, A. HERBERT (M) manager, P. R. Electric Starter Co., *Chicago*, (mail) 120 East 68th Street.

PARSONS, CHARLES EDWARD (M) chief engineer, Deppé Motors Corporation, 151 Church Street, *New York City*.

PETERSON, W. C. (M) metallurgist, Atlas Crucible Steel Co., *Detroit*, (mail) 5174 Parker Avenue.

PHELAN, HERBERT C. (A) tool salesman, Cornwell Quality Tools Co., Cuyahoga Falls, Ohio, (mail) 55 Spring Street, *Portland, Me.*

POWER, E. (M) superintendent of equipment, Union Oil Co., Union Oil Building, *Los Angeles, Cal.*

REINHARD, LOUIS (A) engineer, Geuder, Paeschke & Frey Co., *Milwaukee*, (mail) 709 Hackett Avenue.

ROOKS, ALFRED WENDEL (E S) student, School of Engineering, *Milwaukee*, (mail) 652 Milwaukee Street.

ROSECRANS, CRANDALL (J) research assistant, 102 Mechanical Engineering Laboratory, University of Illinois, *Urbana, Ill.*

ROWELL, HENRY SNOWDEN (F M) director of research, Research Association of British Motor & Allied Manufacturers, 15 Bolton Road, *Chiswick, London, W 4, England*.

RUGE, EDGAR P. (A) road service man, Dorris Motor Car Co., *St. Louis*, (mail) 5053 Kensington Avenue.

RYDER, C. D. (A) chief engineer, Corcoran Victor Co., Cincinnati, (mail) 320 Russell Street, *Covington, Ky.*

SCHROYER, E. C. (J) instructor, Georgia School of Technology, *Atlanta, Ga.*

SCHWARTZ, CHRISTIAN (M) testing engineer, research laboratory, Plant 5, Studebaker Corporation of America, *Detroit*.

SHOEMAKER, HARRY (A) salesman, Girard Automobile Co., *Philadelphia*, (mail) 6404 North 11th Street.

STROHL, GEORGE RALPH (M) mechanical engineer, Autocar Co., *Ardmore, Pa.*, (mail) 520 East County Line Road.

STURTEVANT, FOSTER E. (J) draftsman, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*, (mail) 45 South First Avenue.

TETHER, CLIFFORD F. (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 145 Eighth Street.

TILDEN, SYDNEY G. (J) in charge of wholesale sales, Vandar Motor Sales Corporation, Brooklyn, N. Y., (mail) 223 Woodland Avenue, *New Rochelle, N. Y.*

TRAMMELL, LEANDER NEWTON (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 55 West North Avenue.

ULRICH, THEODORE (J) layout draftsman, Hupp Motor Car Corporation, Milwaukee and Mount Elliott Avenues, *Detroit*.

VIETS, ELTON WILLARD (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 624 Packard Street.

THE

JOURNAL
OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 *W.* 39*th St., New York*

Issued monthly, $1 a number, $10 a year; foreign $12 a year; to members, 50 cents a number, $5 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1918.

B. B. BACHMAN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. X APRIL, 1922 No. 4

INDEX

Activities of the Sections		296
Announcement Regarding Transactions		261
Applicants for Membership		302
Applicants Qualified		301
Battleships versus Airplane Carriers		230
Cross-Country Flying by the Air Service		289
Current Standardization Work		298
Highway Engineering and Transport Education		272
Letter Ballot on Adoption of Standards		260
March Council Meeting		291
Number and Value of Farm Animals		295
Obituary		297
Passenger-Car Brakes — J Edward Schipper		273
Personal Notes of the Members	Adv Section	2
Service-Man's Critical Estimate of Automotive Engineering — B M Ikert		263
Some Aspects of Air-Cooled Cylinder Design and Development — S D Heron		231
Suggested Problems for Research		290
Summer Meeting		229
Tentative Schedule of Division Meetings		292
Value of Standards in Tractor Manufacture — P M Heldt		270
Men Available	Adv Section	48
Positions Available	Adv Section	60

Attention is directed to the special notice regarding the TRANSACTIONS on page 261

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. X April, 1922 No. 4

The Summer Meeting

HAVE your vacation, or a part of it, at White Sulphur Springs, W. Va., during the week of June 18. The Summer Meeting of the Society will be held at this unusually attractive resort during that week. The meeting opens Tuesday, June 20, and closes Saturday, June 24. The hotel authorities have set especially low rates during this meeting period and the fare-and-half return concession has been assured us by the railroads that traverse the automotive districts.

White Sulphur Springs and its environs will appeal strongly to the members of the Society. It is situated on the main line of the Chesapeake & Ohio Railroad, where that line passes through the Allegheny Mountains. The resort proper is at an elevation of 2000 ft. and the surrounding mountains reach to even greater heights. In the warmest season the evenings are cool and refreshing. Two hotels, The Greenbrier and The White, will serve as our home during the meeting. Both establishments are modern in their appointments,

THE GREENBRIER HOTEL, WHITE SULPHUR SPRINGS, W. VA., WHERE THE SUMMER MEETING OF THE SOCIETY WILL BE HELD JUNE 20-24

the cuisine is appetizing and the service is the type that our members demand. A very large percentage of the rooms have connecting baths and there is a large tiled pool for those who enjoy swimming.

The general arrangement of the meeting program will follow closely that which has proved so successful in past years. The mornings will be devoted exclusively to technical sessions at which the engineering, production and service problems of the industry will be treated by authorities and thoroughly discussed in assembly. Although the plans for the technical program are indefinite at this early date, sessions on motor-bus, research, service, aeronautics and fuel matters seem definitely assured. The Meetings Committee is endeavoring to treat those problems whose solution appears to be most urgent at this time. In this endeavor it asks the cooperation of those in the industry whose daily work brings them into intimate contact with the engineering matters that are exciting greatest interest. Write your suggestions to the headquarters of the Society in New York City. If you have a paper that you wish to present personally, send it to the Committee at once.

The Sports

The afternoons at White Sulphur Springs will be devoted entirely to sports. One of the major factors influencing the selection of this resort was its unusually complete sport facilities. There are two picturesque and sporty golf-courses, one of 9 holes and another of 18. Five excellent tennis courts lie adjacent to an attractive clubhouse whose shady verandahs provide a pleasant gallery for the tennis and golf spectators. A baseball diamond awaits the adherents of the national pastime. Trapshooting, bowling, croquet, clock golf and quoits are provided for. A spacious lawn will accommodate the annual S.A.E. games. The 50 x 100-ft. swimming pool will prove alluring to the water lovers. Races will be held in the natatorium on one of the evenings. Our members can readily discern from this outline that White Sulphur Springs holds many attractions for the sport lover.

Reservations for the 1922 Summer Meeting will be made in a manner unlike that followed in past years. On page 37 of this issue of The Journal an application blank is printed for the members' use. Read the instructions carefully to avoid any misunderstanding. You will note that assignments to rooms are made by the hotel. The hotel authorities are not permitted to accept applications for rooms desired during the meeting period, unless these are forwarded through the offices of the Society. Your application blank must be accompanied by the proper reservation fee before it will be accepted and sent to the hotel. This fee applies as a credit on your hotel bill when you check out after the Summer Meeting. Reservations will be assigned in the order of receipt of the applications and those members who mail theirs promptly will receive the benefit of what choice there may be in the selection of rooms. Mail your application today.

BATTLESHIPS VERSUS AIRPLANE CARRIERS[1]

THE Navy Department has a very important problem that one may think has developed largely from the recent bombing tests but it is a problem that has been appreciated from the very beginning of aviation in the Navy. It is that we must get our planes with the fleet. It was not altogether appreciated for a time that the planes with the fleet would be useful for much more than observation purposes and the control of gunfire; but it is now realized very thoroughly that they are an important asset for the purposes of attack and that they are still more important for purposes of defense. The aircraft carrier is coming; it is a necessity, but it is not a reality as yet. There is talk to the effect that the battleship is obsolete, but it is not yet obsolete in my opinion. I think that opinion is held generally by officers of the Naval Service, although there are some who differ. Until we have something to supplant the battleship, we cannot give it up. I really think that the time is coming when the battleship and the aircraft carrier probably will come toward each other and that, ultimately, a new type of battleship will develop therefrom. For that reason I cannot agree that battleships are obsolete. There must be a main factor in a fleet that can control a decision at sea. It will be a long time before it will be possible for any nation to concentrate on any fleet at sea the amount of fire that was concentrated on the ships off the Virginia Capes in the recent bombing-tests.

Another important problem that has been realized from the beginning in the Navy is the necessity of launching airplanes from ships. We have conducted recently successful experiments along this line, and believe that the launching problem is fairly well worked-out. The aircraft carrier itself offers a more simple method of launching and also, what is still more important, a means for aircraft to return to the mother ship. But, when we get the aircraft carrier, what we must do is to carry a flying field at sea. That flying field will be a much larger and more vulnerable target than the battleship itself. The aircraft carrier is subject to surface as well as subsurface attack, just as the battleship is, except of course when we cause it to travel at high speed. When it travels at high speed we get a large aircraft carrier, and then we have a large target. The most important factor is getting the airplanes back again, but it requires only a 600-lb. bomb to smash up a deck so that it is no longer useful for getting airplanes away or landing them; thus the problem will not have been solved even when we get aircraft carriers.

[1] From an address, before the Metropolitan Section's December 1921 meeting, by Com. H. C. Richardson, U.S.N., chief engineer, Naval Aircraft Factory, League Island Navy Yard, Philadelphia.

SCIENCE

SCIENCE as king, science as power, looms as the great new figure, the overshadowing novel factor, in practical statesmanship. Unlike the factor x in the traditional equation, it is the known factor par excellence, the factor by which the value of all the other factors of human life will be ascertained and solved. As knowledge of the conditions determining all life, it stands as the courageous David of the race against the Goliath territory of the uncontrollable and the inevitable, even the unknowable. The future of science has become the future of the race. The natural wonders of the laboratory have taken the place of the absurdities of the medieval mind.—Louis Berman.

Some Aspects of Air-Cooled Cylinder Design and Development

By S. D. Heron[1]

Dayton Section Paper *Illustrated with* Drawings and Photographs

THE paper reviews some of the salient points arising in the design and development of the modern high-output air-cooled cylinder. It is based to a very large extent upon the work of Dr. A. H. Gibson at the Royal Aircraft Establishment, which in turn was principally a development of the pioneer efforts of Renault, supplemented by some post-war work of the author for British companies and tests made by the engineering division of the Air Service. While the paper may, therefore, lack somewhat in originality, many of the results presented, it is stated, have not been published previously. The problems of an aircraft cylinder of approximately 40 b. hp. are dealt with primarily, but some aspects of automobile-engine cylinder design are considered.

The first point treated is the heat to be dissipated, this being followed by a consideration of how to secure an even temperature-distribution in the various parts of the cylinder. Cooling by a direct air-blast and by conduction is discussed, the importance of removing the heat from the cylinder at the point where it is given to the head, the ports and the barrel being particularly emphasized. The effects of mixture-strength and cooling air-supply upon the cylinder temperature are commented on, the text being supplemented by a number of tables. Methods of finning different forms of cylinder, the cooling surface required; the effect of the compression-ratio on the output, fuel-consumption and wall-temperature; cylinder materials; types of cylinder, with a summary of the advantages and disadvantages of the different forms of construction, valve-seat inserts in aluminum cylinder-heads; exhaust-valve cooling; and valve-gears, all receive attention.

The conclusions reached are that (*a*) successful air-cooling is not limited to 50 b. hp. per cylinder, (*b*) fragility of the fins is a disadvantage of air-cooling and (*c*) the compromises necessary in the design of air-cooled cylinders have been made at the expense of the cooling efficiency.

The effect of the position of the spark-plugs on the power output and the fuel-consumption is discussed in an appendix and the use of two spark-plugs located on a common horizontal axis that passes through the vertical axis of the combustion-chamber in such a position that neither plug can project a flame-wave against the exhaust-valves is commended. The influence of gas velocity through the valves on the performance of an air-cooled engine is the subject of a second appendix. In this, as throughout the paper proper, numerous illustrations and tabulations of test results supplement the text.

IT is proposed to review some of the salient points arising in the design and development of the modern air-cooled cylinder of high output.

It may be well to state that the paper contains little that is new, it being based in the main on the work of Dr. A. H. Gibson at the engine research department of the Royal Aircraft Establishment.[2] Some postwar work of mine in British companies is also drawn upon, and the work of the engineering division of the Air Service has been used freely. With few exceptions I have been concerned personally with the types and tests mentioned in the paper, which may cause the views presented to be somewhat one-sided.

Although the paper is lacking in originality, it is felt that many of the data presented are by no means well known to American engineers. In fact part of the data used has never been previously published to my knowledge. The work on which the paper is based is in the main a development of the pioneer efforts of Renault, whose air-cooled aircraft engines established such an enviable record for reliability.

The development of air-cooling in Great Britain is principally due to the brilliant and persistent work of Dr. Gibson, and to the far-sighted enthusiasm of Major F. M. Green, who initiated the investigation at the Royal Aircraft Establishment. In 1915 the air-cooled aircraft engine of stationary type (rotary engines are not dealt with in this paper) was prone to cracked cylinders, burnt exhaust-valves and overheating. At the best, the engines then used developed only low mean effective pressure, and that on high specific fuel-consumption. In fact, the R. A. E. 1A and 4A engine specifications called for a minimum specific fuel consumption of 0.63 lb., a necessary precaution to avoid cracked valve-seats and burnt valves. The progress since 1915 has been rapid. Today the air-cooled engine is not one iota less reliable as regards exhaust-valves, has little higher fuel-consumption and is generally no more liable to thermal trouble than is its water-cooled rival of equal class of design.

Primarily the paper deals with the problems of the aircraft cylinder of about 40 b. hp. In addition, some aspects of automobile-engine cylinder design are touched upon.

Heat to Be Dissipated

Investigation has shown that for every brake horsepower developed an average of approximately 0.6 hp. or 25 B.t.u. per min. has to be dissipated directly to the cooling air by the external cooling surface of the cylinder. In addition, 0.4 to 0.5 hp. has to be dissipated by the oil, by conduction to and radiation from the crankcase and similar means. The amount of heat absorbed by the oil will depend largely upon the amount reaching the cylinder and the piston walls and the facilities for cooling the oil. Power output, fuel consumption and cylinder-wall temperatures, such as are quoted herein, are dependent upon liberal splash lubrication and the resultant oil-cooling.

In the light of present-day knowledge a design for a

[1] S.M.S.A.E.—Aeronautical mechanical engineer, engineering division, Air Service, McCook Field, Dayton, Ohio.

[2] See *Proceedings of the Institution of Automobile Engineers*, vol. 14, p. 243; also *Transactions of the Royal Aeronautical Society*, No. 3; also Internal-Combustion Engine Subcommittee of the British Advisory Committee for Aeronautics Reports Nos. 24 and 41.

cylinder of high output has to fulfill approximately the following requirements:

(1) Develop a volumetric efficiency of 80 to 85 per cent
(2) Produce a brake mean effective pressure of at least 130 lb. per sq. in. at the normal speed on a maximum fuel-consumption of 0.56 lb. per b. hp-hr.
(3) Dissipate 25 B.t.u. per min. per b. hp. from the external cooling surfaces of cylinder, this heat to be dissipated so that the maximum temperature of any portion of the exterior of the cylinder walls does not exceed 550 deg. fahr., and it is preferable that it be lower. In addition, the mean temperature of the exterior of the cylinder walls should not exceed 350 deg. fahr. To produce a layout that fulfills the stated requirements, it is necessary that heat-flow be the primary point in mind during design.

TEMPERATURE DISTRIBUTION

As the amount of heat lost to the walls from the charge differs largely in various parts of the cylinder, it is obvious that to have anything like even temperature-distribution, the supply of cooling air to any portion of the cylinder should be proportioned approximately to the amount of heat given to that portion of the cylinder.

Considering a normal design of overhead-valve cylinder with circumferential cooling-fins, it is evident that the side of the cylinder-head and barrel that carries the exhaust ports will receive the greatest heat supply per unit area, and therefore should receive the major portion and the greatest effect of the cooling air-supply. This requirement is suitably met by applying the cooling blast on the exhaust side of the cylinder. In practice, with such blast application, the circumferential temperature-difference at the top of the cylindrical portion of the combustion-chamber will not exceed 50 deg. fahr. Toward the base of the cylinder the circumferential temperature-differences will probably increase, but this is usually of little moment, since the maximum temperatures attained there are low. Contrary to the opinion commonly held in this Country, the back or side of the cylinder that is in the lee of the blast, does not give overheating trouble when the cylinder design is sound and the air supply is suitably arranged.

Uneven temperature distribution, whether caused by poor air distribution or by cylinder walls lacking the required heat-flow capacity to equalize the temperature distribution, has a considerable effect on the output, thermal efficiency and reliability of a cylinder. Very uneven distribution of temperature will result in the local development of an excessive temperature and overheated exhaust-valves. These faults in their turn lead to decreased volumetric efficiency and the use of rich mixtures to check detonation, to reduce the flame temperature and to cool the walls internally.

The tendency to detonation resulting from local or general high cylinder-wall temperature reduces the maximum usable compression-ratio, thus doubly reducing the possible output.

DIRECT COOLING VERSUS COOLING BY CONDUCTION

The advent of aluminum as a cylinder material, and the success obtained with some of the early applications of it, resulted almost immediately in the production of many designs that gave poor results. For a time it was commonly thought that aluminum would, by its high conductivity carry away efficiently the heat from the portions of a cylinder that are entirely inaccessible to the cooling air and have, in addition, the maximum heat-reception. On the surface such a method seems to be the obvious way of avoiding the apparent difficulties of directly air-cooling all portions of the cylinder. Experience, however, has shown that to produce an air-cooled cylinder that is comparable in output with a high-class water-cooled design, the cooling medium must flow over all portions of the cylinder-head and barrel. Air will not flow around sharp corners or through fins at 90 deg. to the airstream merely to fit in with the imagination of the sanguine designer. Numerous tests have demonstrated that siamesed exhaust-ports, and exhaust and intake ports without any air space between them, are altogether unsound. This is markedly comparable with experience on water-cooled cylinders of high output.

The aim in design should be to remove as far as possible the heat from the cylinder at the point where it is given to the head, ports and barrel. Investigation has demonstrated that neither a material of high conductivity nor an excessive cooling air-supply will remedy poor design. A simple cast-iron cylinder with only a small cooling air-supply but fulfilling some of the fundamental necessities for efficient heat-dissipation will give a performance much superior to that of designs that presume to function by high wall or fin conductivity in conjunction with large quantities of air supplied to those portions of the cylinder where little is needed and a total lack of effective air-supply where it is required.

EFFECTS OF MIXTURE-STRENGTH AND COOLING AIR-SUPPLY UPON CYLINDER TEMPERATURE

The temperature of an air-cooled engine is determined by the cooling-air temperature as a datum point. If the air temperature rises 50 deg. fahr., the actual cylinder temperatures are sensibly increased by that amount. In general, with an efficient cylinder design, the effect of the air temperature is little felt. A considerable rise in the air temperature increases the cylinder temperature, but it simultaneously reduces the charge weight, and thus to some extent the heat to be dissipated by the cylinder is diminished. A variation of 350 deg. fahr. in maximum cylinder-temperature at full throttle is permissible for short periods of time, such as exist during a fast steep climb by an airplane or the ascent of a mountain pass by an air-cooled car. That cylinder-temperature control is necessary for air-cooled aircraft engines has yet to be proved in practice, although urged as a disadvantage of air-cooling by its opponents. The stabilization of the carbureter temperature is much more likely to be found necessary, due to the rapidity with which an air-cooled engine cools during a glide or dive when switched off or idling.

An investigation of the amount of air required to carry away the heat dissipated from the external cooling surfaces of air-cooled cylinders is of considerable interest. For aircraft it is desirable to use as little cooling air as possible to minimize the head resistance. For automobile work, where fan cooling is used, economy of power absorbed by the fan is to be aimed at. In both cases, however, economy in the cooling air-supply may be dearly bought. A possible result of insufficient cooling air-supply is a hot engine, requiring more fuel for a given net performance than an engine supplied with more cooling air, and having a lower specific fuel-consumption per overall horsepower which is the effective horsepower plus the horsepower absorbed in cooling. I know of no exact measurements of the cooling air-supply in connection with the general type of cylinder dealt with in this paper. Tests have been conducted to measure the amount of cooling air required and the mean temperature-rise of the air, but these were carried out before the specific output had reached its present figures.

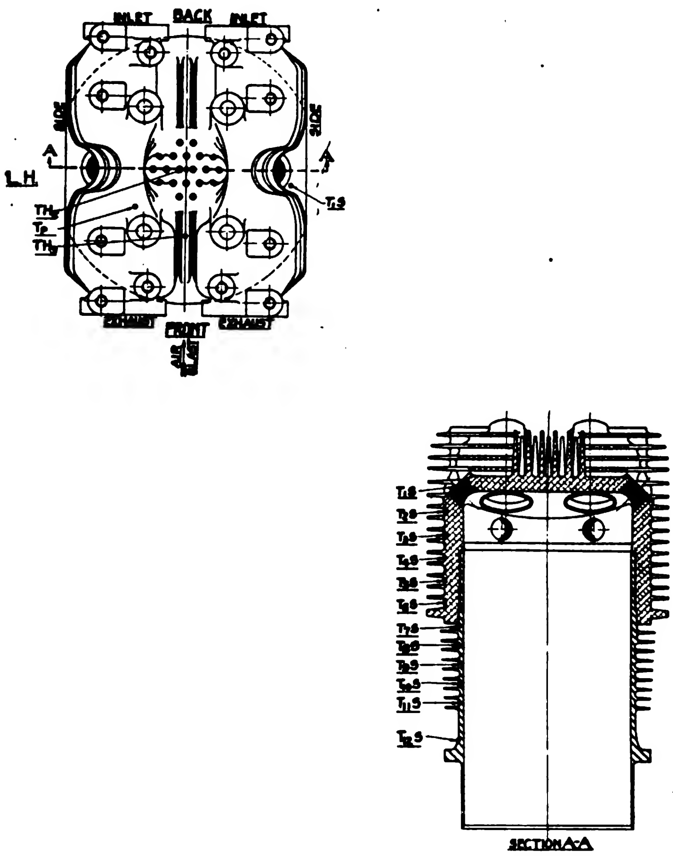


FIG. 1—TEMPERATURE POSITIONS OF THE AIRCO CYLINDER

An attempt is made herein to estimate the quantity of air used for cooling a circumferential-fin cylinder by a free, unconfined, blast. The method used is not exact by any means and is open to criticism, but other data on cylinders of such size and efficiency are lacking. The cylinder used is the Airco of 5½ x 6 in., shown in Fig. 1, developing 46.5 b. hp. at 1900 r.p.m., or a brake mean effective pressure of 136 lb. per sq. in., and running in a mean blast of 87 m.p.h., this velocity being the mean of the velocities measured around the outside of the air-flow area contour shown in Fig. 2. The cylinder is assumed to be cooled so that all air supplied passes between the fins. It is assumed also that the air velocity is constant from the roots to the tips of the fins. The air-flow area diagram, Fig. 2, takes no account of the fin thickness and otherwise gives a generous estimate of area available for flow. This area, from the diagram, is 32 sq. in.

The quantity of air used on the above basis is 1700 cu. ft. per min. and is the product of the blast velocity in feet per minute and the area available for flow in square feet. The number of cubic feet required per minute per brake horsepower is 36.7. The heat to be dissipated per min. per b. hp. is 25 B.t.u., or a total of 1160 B.t.u. per min. The weight of air required per minute is 129 lb. The mean temperature-rise of the air is equal to the total number of British thermal units dissipated per minute divided by the weight of air required times the specific heat at constant pressure, or $1160 \div (129 \times 0.24) = 37$ deg. fahr.

The cylinder used in this example is, of course, a highly efficient design, running under nearly ideal conditions. In fact, few air-cooled cylinders of such size have given better performance at a similar speed. The cylinder was running at continuous full-throttle, and even under these circumstances a considerable reduction in the blast velocity could have been made without materially affecting the performance or the temperature. Under conditions of intermittent full-throttle operation or the equivalent of progressively throttling that approximates the condition of a steady climb by aircraft, a considerable reduction of air supply could be made with safety.

Owing to the fact that the cylinder was operating in a free blast, much of the air supplied was not actually used for cooling, due to it striking the front of the cylinder and being deflected sideways and thus not passing through the fins at the cylinder sides. This may be an objection to the method used for estimating the air supply. Single cylinders have shown approximately the same performance when cowled so that all the air supplied was effective for cooling, as when running in a free blast of equal mean velocity.

In cowled V-engines, where the cooling air is supplied to the V and flows out sideways between the cylinders, all the air available for cooling has to pass through the fins and some of these engines have given remarkably

FIG. 2—CROSS-SECTION OF THE AIRCO CYLINDER SHOWING THE AREA AVAILABLE FOR USEFUL COOLING-AIR FLOW

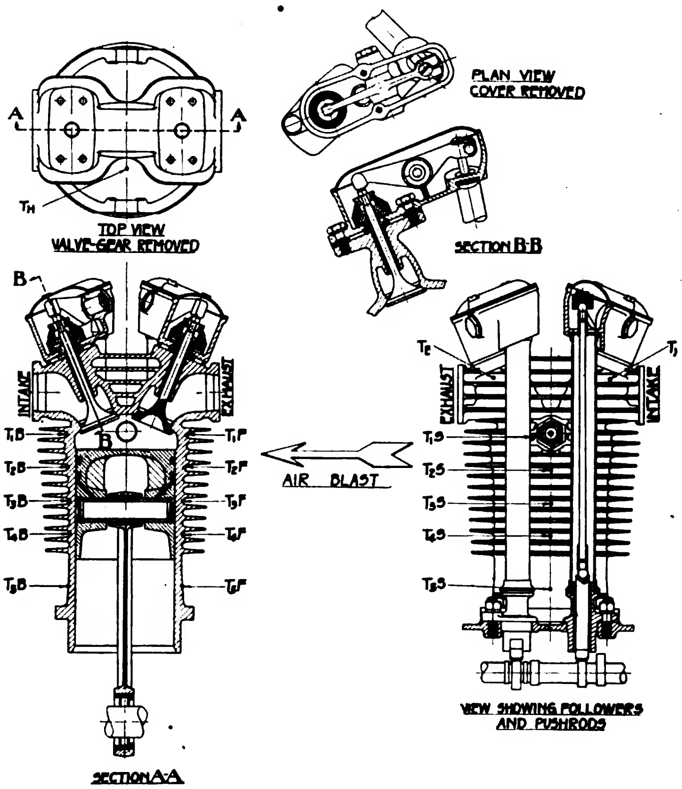


FIG. 3—PLAN VIEW AND SECTIONAL ELEVATIONS OF THE CYLINDER USED IN THE B. S. A. PASSENGER CAR

efficient cooling. Examples of engines thus cooled are the Renault and the R.A.E. 1A, 4A and 4D engines.

Numbers of designs have been proposed and many built in which the ingoing charge is presumed to cool the various parts of the cylinder, usually the exhaust-valves and exhaust-ports. In practice such designs do not function, little or no cooling from the ingoing charge is obtained, and the general result is usually a marked reduction in the volumetric efficiency, accompanied by a pronounced overheating. The ratio between the amount of air required for cooling and that used for combustion serves to show the unsoundness of attempts to use the ingoing charge for cooling. Further, the cylinder is not the correct place to apply heat to the charge, as heat supplied there can have no beneficial effect on the distribution. In calculating the air required for combustion a brake mean effective pressure of 130 lb. per sq. in. and an 85-per cent volumetric efficiency in terms of air at the carbureter mouth are assumed. This brake mean effective pressure almost exactly equals 6.1 cu. in. cylinder capacity per brake horsepower in a four-cycle engine running at 1000 r.p.m. The volume of air per brake horsepower per minute required for combustion is 1.5 cu. ft. and the ratio between the air for required cooling and that needed for combustion is 24.5:1 or 36.7/1.5. Although less than 36.7 cu. ft. of cooling air per b. hp. can be used, and the foregoing calculation takes no account of the cooling effect derived from the latent heat of the unevaporated fuel, nevertheless it gives a measure of the unsoundness of a method of cooling so attractive to many.

An example of what may be accomplished in the way of automobile engine cooling with small air-supply is shown by the B.S.A. Light Car, the cylinder of which is shown in Fig. 3. This car has a 90-deg. two-cylinder V-engine of 66-cu. in. capacity and is cooled entirely by natural draft, no fan being employed. One of the early engines was fitted to a car weighing 1700 lb., including passengers and regular equipment, and road tests of the cylinder temperature under these conditions are not without interest. Climbing a hill rising 1200 ft. in 2½ miles, the temperature at *TH*, the hottest point of the hottest cylinder, was 310 deg. fahr. above the air temperature at the start of the ascent, and 495 deg. fahr. at the finish. This ascent was taken on the run with the engine at normal temperature and was made in a following wind in 11 min. There is little question that the heat-storage capacity of the cylinders is of considerable importance in preventing overheating under such conditions as quoted for this car when hill-climbing with a following wind. The heat-storage capacity of a water-cooled car engine having a large quantity of water in the jackets and the radiator, in this sense a heat accumulator, is known to be of advantage in preventing boiling in mountainous country. This is a parallel tending to show the similar advantage of thick, heavy cylinders for air-cooled cars.

Assuming the average brake horsepower as 10, the mean temperature-rise of the cylinder bodies as 100 deg. fahr. and the weight of the two cylinder bodies as 44 lb., the heat given to cylinders during the climb equals 2750 B.t.u. The heat storage of the cylinders for a given temperature-rise equals the product of the weight of the cylinder bodies, the specific heat of the material and the temperature-rise, or $44 \times 0.12 \times 100 = 528$ B.t.u. Therefore, 19 per cent of the heat given to the cylinders during the climb was stored therein. This calculation is, of course, only approximate. The assumptions as to the brake horsepower and the mean temperature-rise of the cylinders are reasonably sound, and even if inaccurate

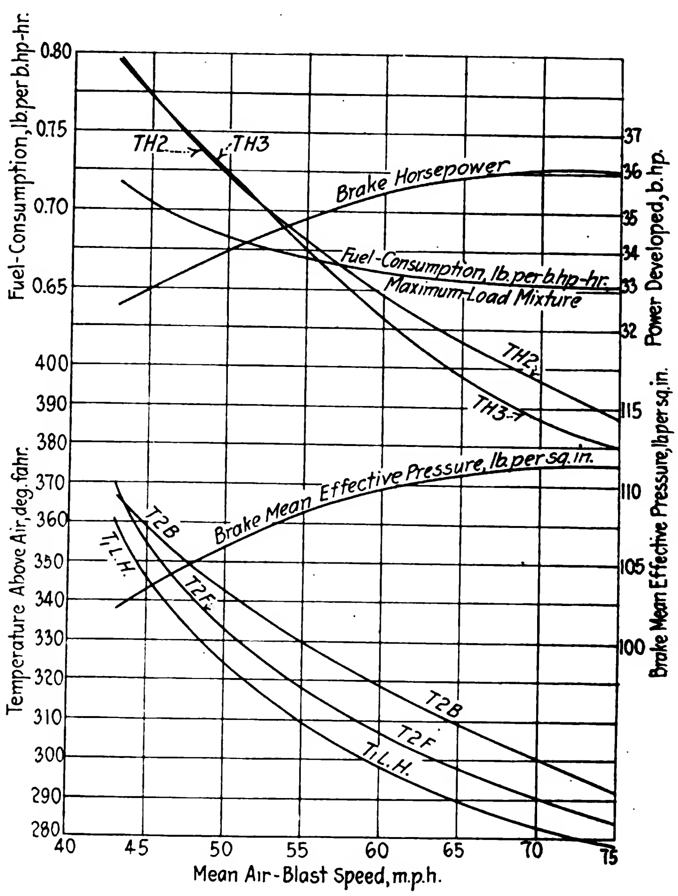


FIG. 4—EFFECT OF THE VARIATION OF BLAST VELOCITY UPON THE TEMPERATURE AND FUEL-CONSUMPTION OF THE AIRCO CYLINDER

the result serves to show the advantages of heavy cylinders with large heat-storage capacity for engines depending almost entirely on radiation for cooling during limited periods of full-throttle operation.

The variation of the cylinder temperature, the output and the fuel-consumption on a maximum load mixture over a range of blast velocities for an Airco cylinder is shown in Fig. 4. It will be noted that a reduction of the blast velocity involves an increase of the fuel-consumption and the cylinder temperature, and causes a drop in the power. It is of interest to note that in this case the circumferential temperature-differences are reduced by a decrease of the blast velocity.

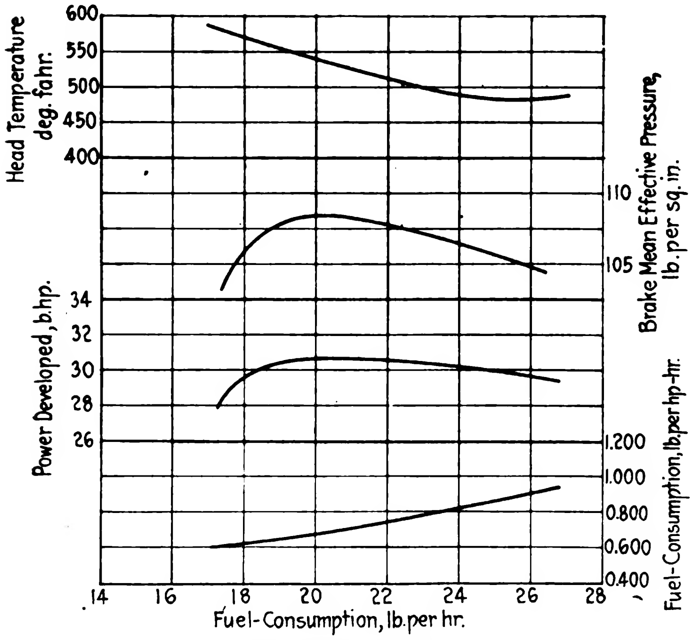


FIG. 5—THE EFFECT OF FUEL-CONSUMPTION UPON THE OUTPUT AND HEAD TEMPERATURE OF A TYPE D CYLINDER

The results of an investigation of the effect of mixture-strength upon the cylinder temperature are shown by Fig. 5. These tests were carried out by the engineering division on a Type D cylinder shown at the left of Fig. 6. The Type D cylinder is not of very efficient design; therefore the results of tests on an R.A.E. 21TD cylinder, shown at the right of Fig. 6, are included and are presented in Table 1. The R.A.E. 21TD cylinder, which is of similar size and design to the Type J cylinder, illustrated in Fig. 7, is thermally of much superior design to the Type D.

TABLE 1—EFFECT OF MIXTURE-STRENGTH ON CYLINDER TEMPERATURE

Power Developed, b. hp.	Fuel-Consumption, lb. per b. hp-hr.	Air-Fuel Ratio by Weight	Difference Between Cylinder-Head Temperature and Air, deg. fahr.
32.8	0.70	10.5	319
33.2	0.64	11.4	345
33.3	0.57	12.9	385
32.9	0.54	13.5	371
30.6	0.51	15.4	345

The marked effect of the mixture-strength on the cylinder temperature is shown also in the results of engineering division tests on the Type D cylinder. It will be noted in Fig. 8 that reducing the blast speed by 50 per cent and simultaneously increasing the fuel-consumption

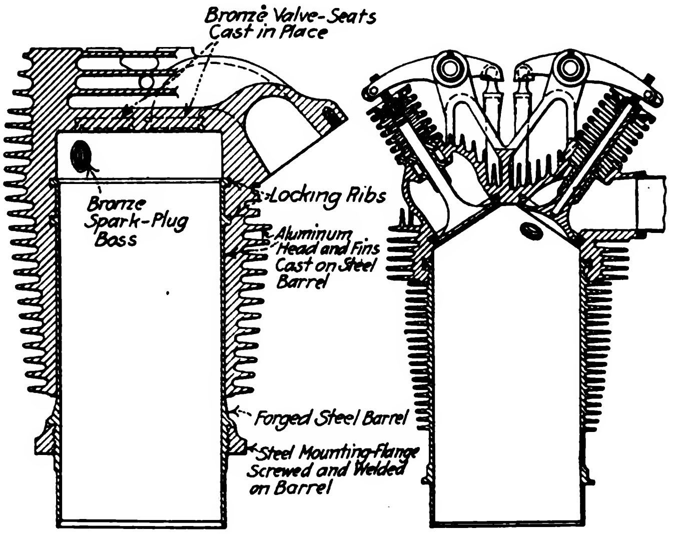


FIG. 6—SECTIONAL ELEVATIONS, AT THE LEFT, OF THE TYPE D CYLINDER DEVELOPED BY THE ENGINEERING DIVISION OF THE AIR SERVICE AND AT THE RIGHT THE 21TD CYLINDER WITH CAST-ON ALUMINUM HEAD DEVELOPED BY THE ROYAL AIRCRAFT ESTABLISHMENT

by 40 per cent, resulted in practically no change in output and only 70-deg. rise in temperature at the hottest point.

The interconnected effects of the mixture-strength and the air supply on the cylinder temperature are of considerable importance in military aircraft service. Overheating, if occurring during a steep climb at a low air-speed, can be largely eliminated by the use of the mixture control on the carbureter. Very high air-temperatures such as exist in tropical climates may cause overheating. This tendency can be reduced also by the use of richer mixtures, although in general, with efficient air-cooling, the effect of the air temperature is of little importance. Almost any crude and inefficient design of air-cooled cylinder can be kept at an efficient working temperature by running it on a sufficiently rich mixture. In fact, it is possible on almost any air-cooled engine to keep the exhaust-valves dead-black by rich mixture.

A cylinder of sound design, when running at its most suitable compression-ratio, will usually develop its maximum power, maximum cylinder-wall temperature and

FIG. 7—TWO VIEWS OF THE TYPE J CYLINDER DEVELOPED BY THE ENGINEERING DIVISION OF THE AIR SERVICE

maximum tendency to detonation when the air-fuel ratio, by weight, for gasoline and gasoline-benzol mixtures is between 12 and 13 to 1. This mixture-strength gives approximately the maximum rate of flame propagation. A mixture-strength of 12 or 13 to 1 by weight, when used on the composite aluminum and steel aircraft cylinder, usually results in a fuel consumption of approximately 0.55 lb. per b. hp-hr. with aviation gasoline or aviation gasoline and benzol. This, however, only applies at the most suitable compression-ratio. If the ratio be too high, fuel-consumptions have to be increased to eliminate detonation. That a fuel consumption of approximately 0.55 lb. per b. hp-hr. usually produces the maximum power and the maximum cylinder-temperature is confirmed by Tables 1 and 2.

TABLE 2—OUTPUT, TEMPERATURE AND FUEL-CONSUMPTION OF THE AIRCO CYLINDER

The maximum exhaust-valve temperature is usually produced by approximately the optimum mixture-strength of 15.2 to 1. The use of such mixtures is, however, impossible on anything but a first-class design. This question is dealt with later under the subject of exhaust-valve cooling.

The specific figures quoted for the mixture-strength will doubtless be productive of criticism, since mixture-strength figures are tied up in the vexed question of volumetric efficiency. On the subject of the volumetric efficiency of cylinders of such outputs as are quoted in this paper, no two investigators seem to be in agreement. The figures in which I have the most cause for confidence are therefore used.

The minimum fuel-consumption that an air-cooled cylinder will run on is generally a measure of its soundness. In this respect a rather curious difference is noticeable between efficient and unsound design. A poor design will usually work over a wide range of fuel-consumption, say from 0.7 to over 1.0 lb. per b. hp-hr., without much variation in the power output, whereas an efficient design will generally show a drop in the power output if the fuel-consumption at maximum load of approximately 0.55 lb. be increased by about 15 per cent, the power progressively decreasing with a further increase of the mixture-strength.

The reduction in the cylinder-wall temperature obtained when the mixture-strength is enriched beyond 12 or 13 to 1 may be attributed to the increase of internal cooling by the evaporation of liquid-fuel particles, and to the reduction of both the rate of flame propagation and the flame temperature.

The relative importance of blast direction for fairly large cylinders is indicated by Table 3, which gives figures of tests on an Airco cylinder with the blast on the exhaust and on the inlet sides of the cylinder, the temperature positions being shown in Fig. 1.

The circumferential temperature-differences at T_2, around the cylindrical portion of the combustion-chamber, with a change of the blast direction are noticeable. With exhaust-side blast the difference is 33 deg. fahr., and with inlet-side blast it is 301 deg. fahr. The increase with inlet-side blast of 197 deg. fahr. in temperature at TH_3, the hottest point of the cylinder, is sufficient in itself to show the marked effects of blast direction. With inlet-side blast the fuel-consumption, although only slightly higher at the maximum-load mixture, could not be reduced as much as with exhaust-side blast. The minimum fuel-consumption with the inlet-side blast was 9 per cent higher than that obtainable with the blast on the exhaust side.

With fairly large two-valve cylinders such as the Type

TABLE 3—EFFECT OF BLAST DIRECTION

Blast Applied on		Exhaust Side	Inlet Side
Mean Blast Velocity, m.p.h.		75.0	70.0
Power Developed, b.hp.		36.4	35.9
Brake Mean Effective Pressure, lb. per sq. in.		119.0	117.2
Fuel-Consumption with Maximum-Load Mixture, lb. per b. hp-hr.		0.66	0.68
Cylinder Temperature-Rise above Air Temperature, deg. fahr.	TH_2	371	402
	TH_3	373	570
	T_2LH	252	293
	T_2 (Exhaust Side)	234	472
	T_2 (Inlet Side)	267	171

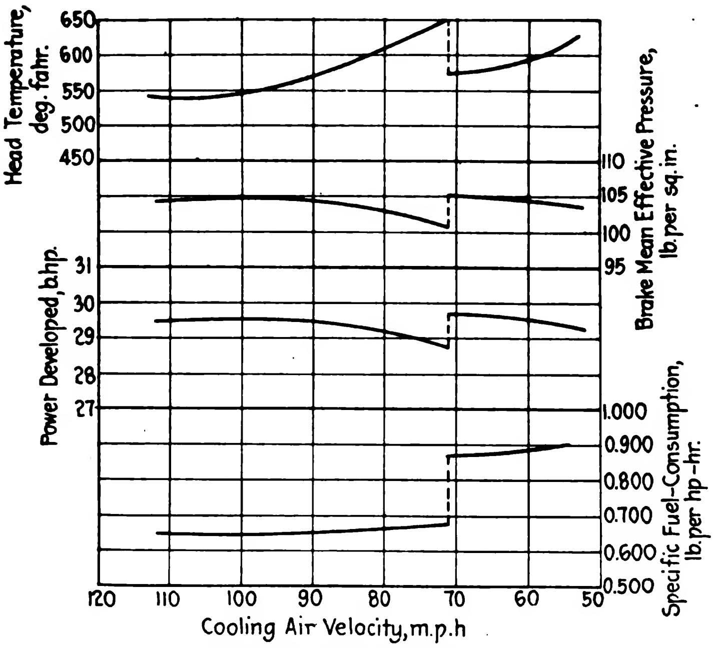


FIG. 8—EFFECT OF VARIATION OF BLAST VELOCITY UPON THE FUEL-CONSUMPTION AND HEAD TEMPERATURE OF THE TYPE D CYLINDER

J cylinder, Fig. 7, it is possible and practicable to direct the blast at 90 deg. to the exhaust side of the cylinder. In the Type J cylinder the exhaust port is located at 75 deg. to the direction of motion of the airplane. The spiral deflection of the propeller slipstream, however, results in the effective angle between the exhaust side of the cylinder and the blast becoming approximately 65 deg. Other than exhaust-side blast for cylinders of over 100 cu. in. capacity is in the nature of a compromise. Exhaust-side blast is always preferable and is almost essential for three and four-valve cylinders.

METHODS OF FINNING

The circumferential fin, on the whole, appears to have the majority of the advantages. It gives a considerable stiffening effect to the cylinder that is of advantage in resisting distortion under temperature, explosion and bending stresses. Circumferential finning in general simplifies the problem of best applying the air-supply to the cylinders. A combination of circumferential fins for the barrel and the cylindrical portion of the head with circumferential and axial fins or axial fins alone for the crown is used at times and is practically essential for four-valve roof-head types.

In the foundry a cylinder with circumferential finning is a decidedly superior production proposition to one completely finned with radial axial fins. The pivotal point in the design with a cast air-cooled cylinder or head is really foundry production. It is useless to produce a design that will not mold readily. The B.S.A. car cylinder shown in Fig. 3 is an example of a simple casting. This was designed for jolt-ram machine-molding, with stripping-plate patterns. The mold and the core are symmetrical about the joint line, with the result that only half a pattern is required for machine-molding and the core cannot be inverted in the mold. Further, not a single loose piece is necessary on the pattern. Such a design from the foundry standpoint can hardly be equalled by water-cooled cylinders, but unfortunately this is possible only with moderate-size cylinders and where the engine is laid-out around the cylinder, which is really required by air-cooled design in the present state of knowledge.

The use of axial radial fins makes it extremely difficult to provide any effective finning of the cylinder crown, and most types of such cylinder exhibit a singular bareness as regards such finning. It is, of course, easy to design a crown covered with fins, but to produce a fin layout for it that can be cast readily and that will give an efficient air-flow through the fin spaces is another matter.

The finning and cooling of the cylinder-head is much more important than that of the barrel. Most axial-fin designs rely upon the barrel finning to cool the cylinder crown, a very thick crown being used to conduct the heat from the center of the head to the barrel. Such practice is not sound, as it places a double duty upon the finning of the combustion-chamber sides and, further, the heat is not dissipated from the crown at the point of its reception. Attempts to use such a construction, although producing passable results in cylinders of small capacity, have, in Europe at any rate, invariably given trouble when applied to cylinders of over 100 cu. in. capacity. Reliable figures have yet to show that such a design in any size can compare in performance with cylinders in which an attempt is made to dissipate the heat at its point of reception.

Overheating of the lee side of a circumferentially finned cylinder does not occur in a cylinder of correct design. The view generally accepted in this Country that overheating of the lee side of a circumferentially finned cylinder is inevitable has arisen mainly from the performance of very light steel aircraft-engine cylinders, mostly of European origin, and all of poor design. Thin cast-iron cylinders with the air-supply unsuitably arranged have also helped to confirm the fears of lee-side overheating.

The figures in Table 2 and the curves reproduced in Fig. 4, showing tests on the composite aluminum and steel Airco cylinder, and those in Table 4 showing the temperature distribution in the cast-iron B.S.A. cylinder, indicate that an even temperature-distribution is ob-

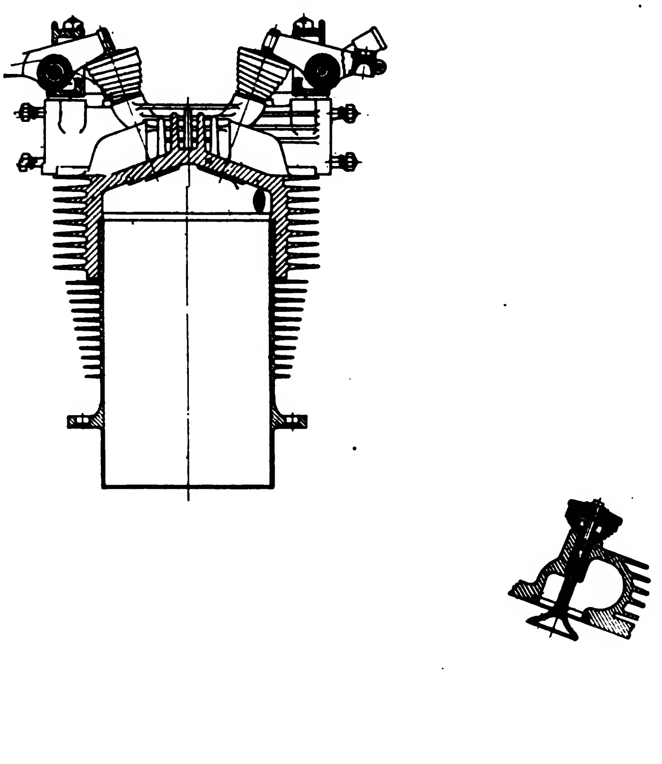


FIG. 9—PLAN VIEW AND SECTIONAL ELEVATIONS OF THE AIRCO 5½ x 6-IN. CYLINDER

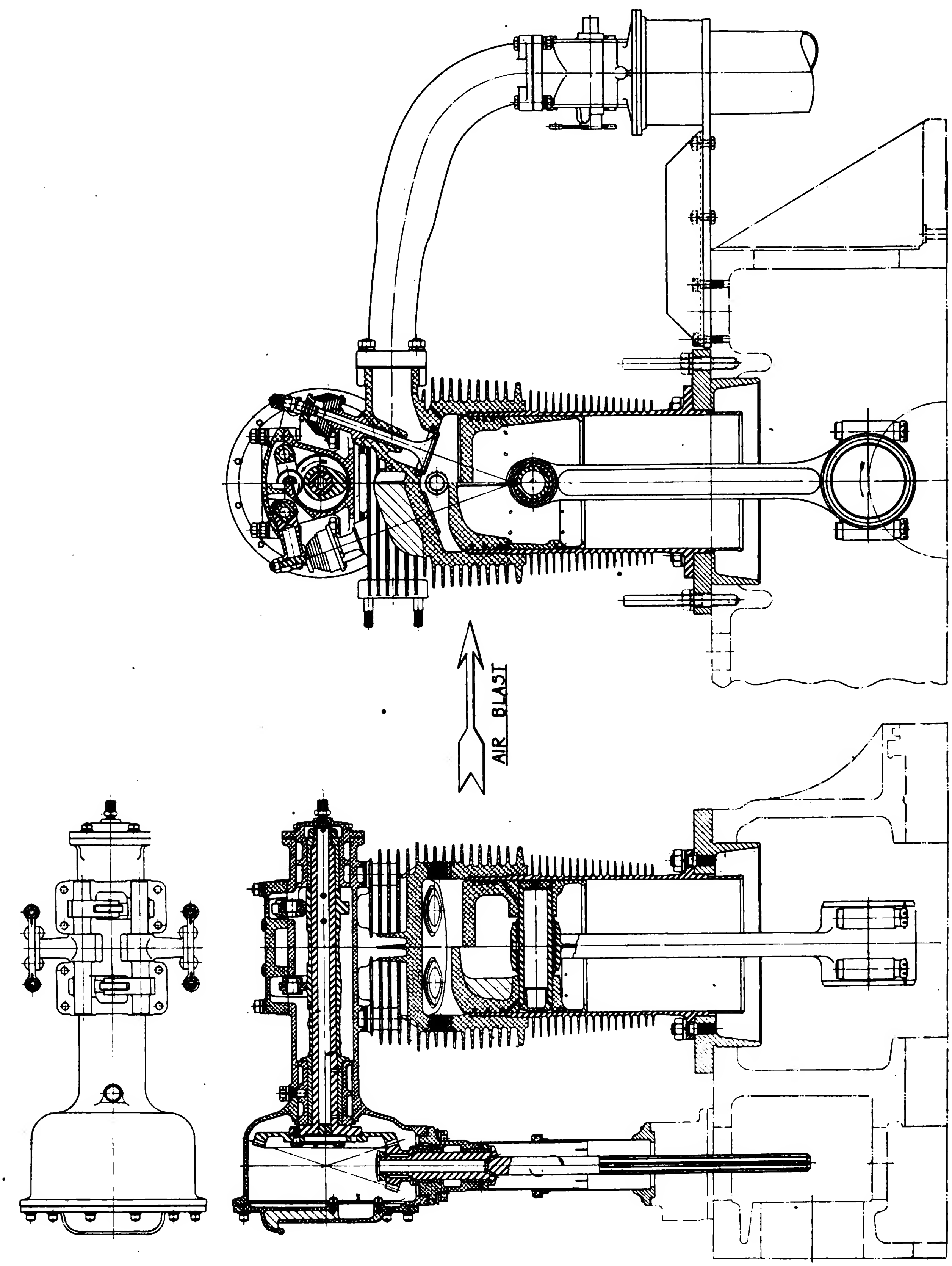


Fig. 10—Assembly Drawing of the Type H Air-Cooled Cylinder Developed by the Engineering Division of the Air Service

tainable with circumferential finning and, further, that such distribution is not dependent upon the use of material of high conductivity.

It will be noticed from Fig. 4 that reduction of blast velocity tends to diminish the circumferential temperature-difference at points T_2. A comparison of the circumferential temperature-difference given in Fig. 4 with those shown in Table 2 indicates that those in the table are the larger. This is partly due to the increased blast velocity, but mostly to the reduced wall-thickness of the head, the cylinder body used for the Fig. 4 tests being that shown in Fig. 1 which was lightened by 15 per cent, as shown in Fig. 9, for the tests given in Table 2.

In connection with Airco cylinder tests it is well to mention that those given in Table 3 and Fig. 4 were obtained while developing the design and the results are therefore relatively poor, due mainly to thermal troubles with valve-seat inserts.

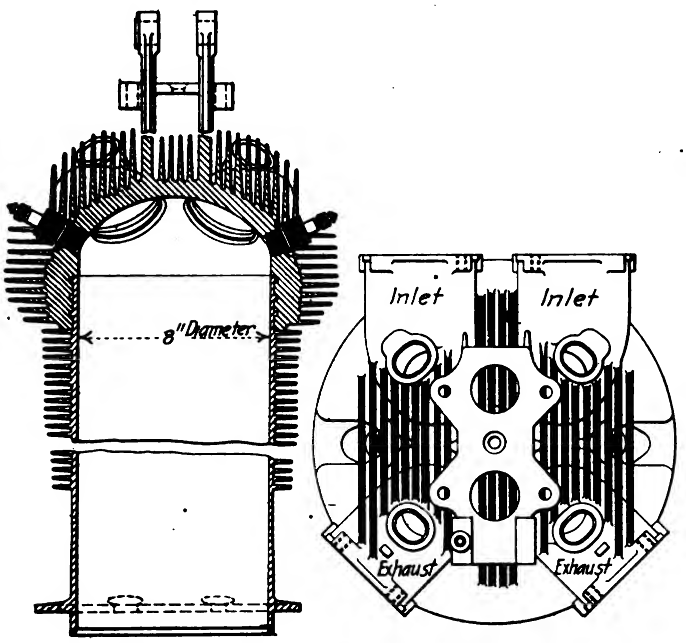


FIG. 11—PLAN VIEW AND SECTIONAL ELEVATION OF THE 19T 8 x 10-IN. CYLINDER WITH CAST-ON ALUMINUM HEAD DEVELOPED BY THE ROYAL AIRCRAFT ESTABLISHMENT

TABLE 4—TEMPERATURE DISTRIBUTION IN THE B. S. A. LIGHT CAR CYLINDER

Bore of Cylinder, mm.	90
Bore of Cylinder, in.	3.54
Stroke, mm.	85
Stroke, in.	3.35
Volume of Cylinder, cu. in.	33
Speed, r.p.m.	1,000
Power Developed, b. hp.	4.36
Brake Mean Effective Pressure, lb. per sq. in.	104.5
Fuel-Consumption, lb. per b. hp-hr.	0.60
Fuel	75 per cent Gasoline and 25 per cent Benzol
Compression-Ratio	4.7 to 1
Mean Blast-Velocity, m.p.h.	40
Blast Applied on	Exhaust Side

Cylinder Temperature-Rise above Air Temperature, deg. fahr.

Temperature Position	Side	Back	Front
TH	384	...	...
T Inlet	130	...	...
T Exhaust	294	...	...
T_1	299	274	301
T_2	276	...	...
T_3	230	...	...
T_4	211	...	...
T_5	167	155	202

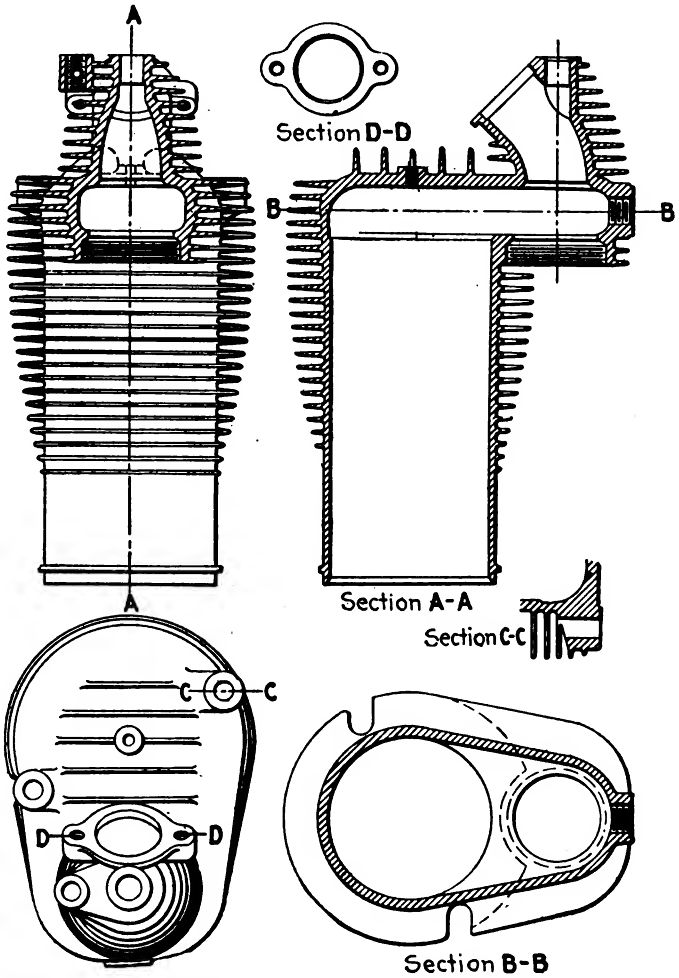


FIG. 12—THE 4A CAST-IRON CYLINDER BODY DEVELOPED BY THE ROYAL AIRCRAFT ESTABLISHMENT

The influence of the thickness of the cylinder barrel at the base may be noted in the figures for the B.S.A. and Airco cylinders, the circumferential temperature-difference of the former cylinder being less than half that of the latter.

The tests reported in Table 4 by no means represent the best obtainable from this cylinder. The low brake mean effective pressure was due largely to poor distribution and very high manifold-depression. The high fuel-consumption obtained was due to the characteristics of the carbureter, a consumption of 0.54 lb. per b. hp-hr. having been obtained later. This engine at a further

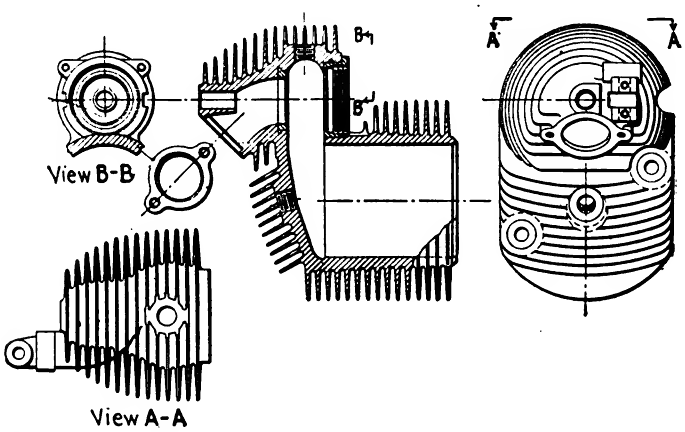


FIG. 13—THE ALUMINUM HEAD AND JACKET OF THE 4C CYLINDER DEVELOPED BY THE ROYAL AIRCRAFT ESTABLISHMENT

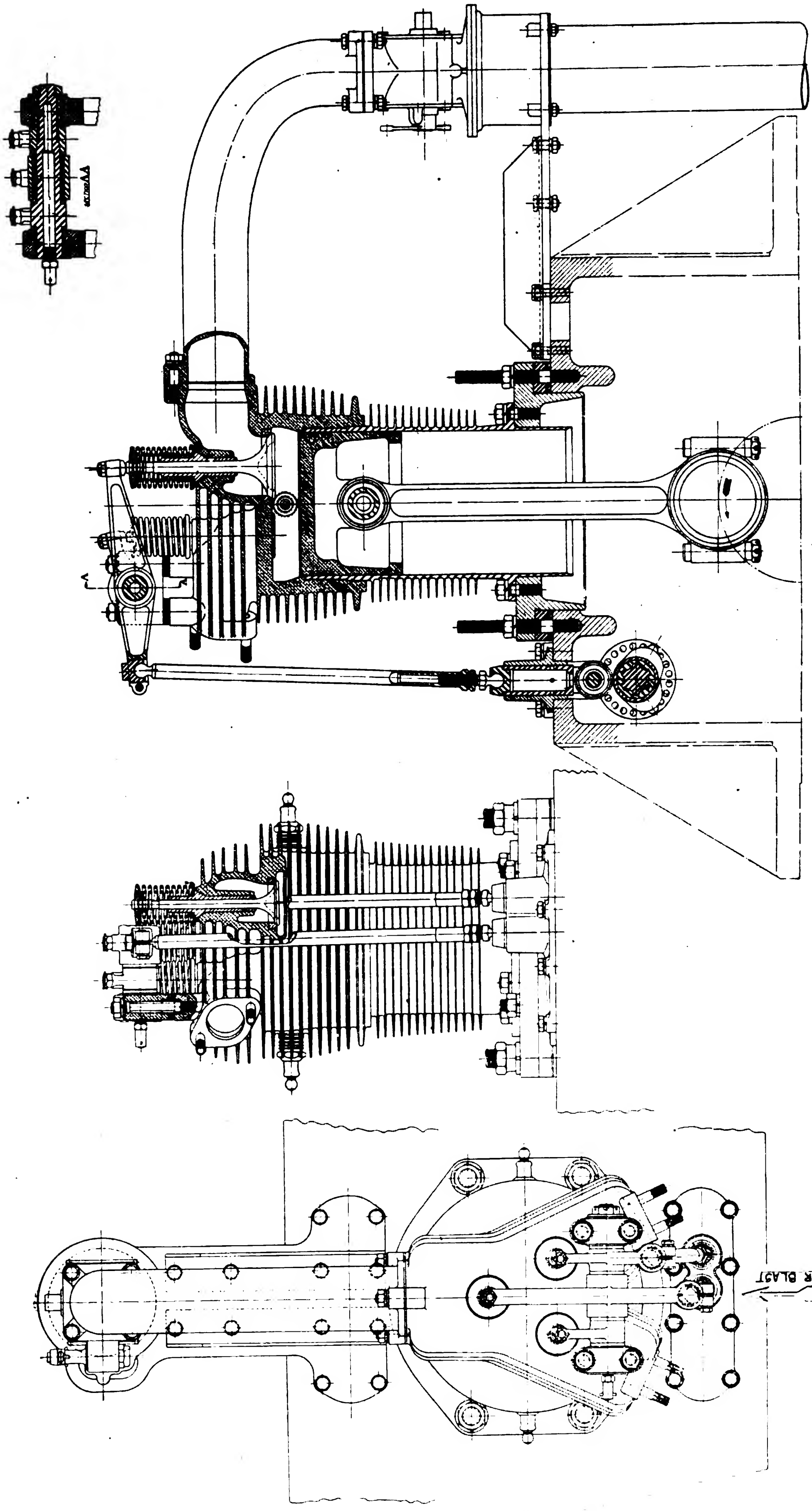


FIG. 14—ASSEMBLY OF THE TYPE I AIR-COOLED CYLINDER DEVELOPED BY THE ENGINEERING DIVISION OF THE AIR SERVICE

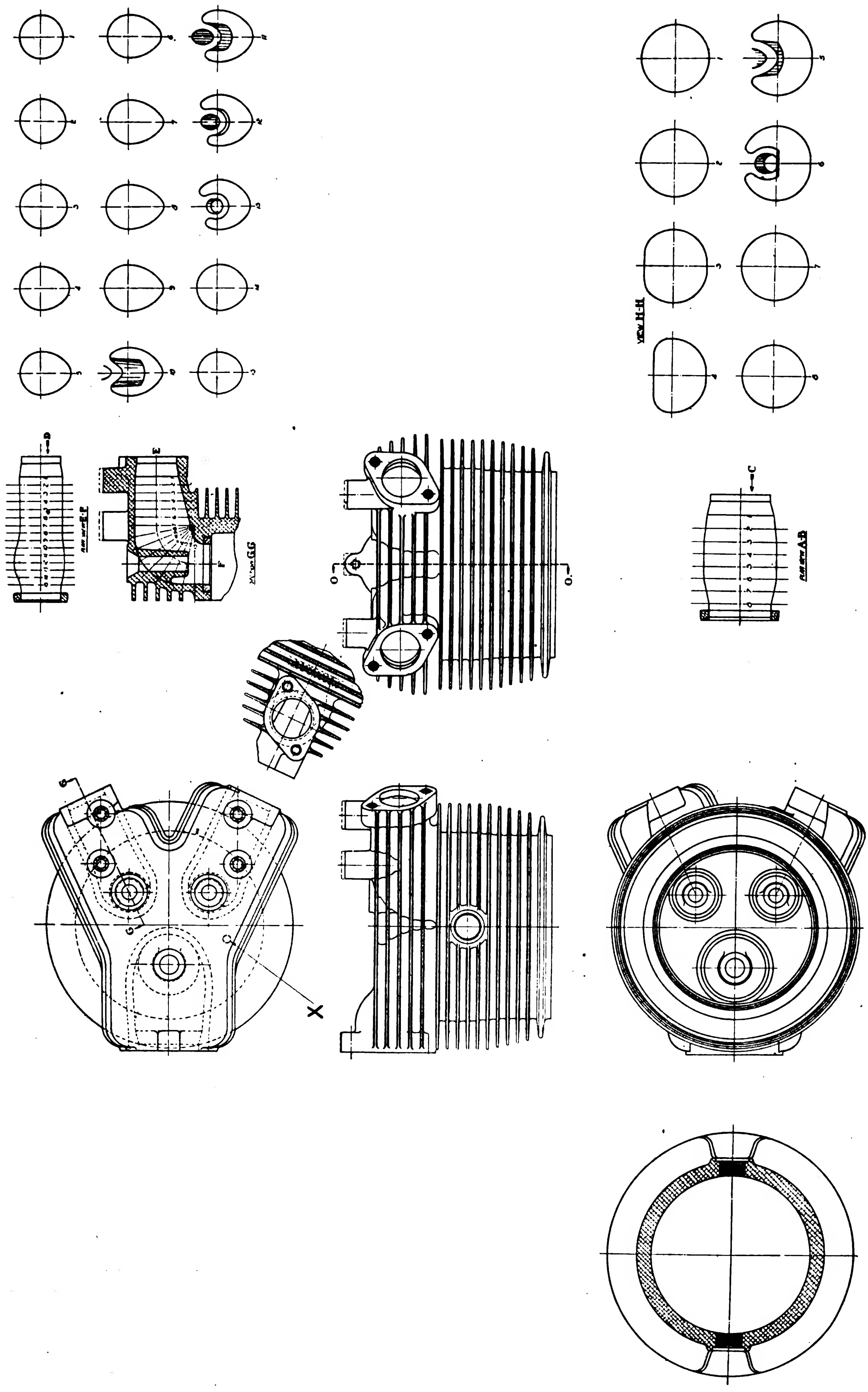


Fig. 15—Head for the Type I Air-Cooled Cylinder

stage of development and when using slightly higher compression has given 120 lb. brake mean effective pressure at 1800 r.p.m. The figures presented seem to indicate the soundness of circumferential finning for a wide range of cylinder sizes and classes of duty.

Many methods of finning are seen in the various illustrations. The Airco cylinder, Figs. 1 and 9, has a combination of circumferential and vertical fins in conjunction with spikes for the center of the crown; the Type H cylinder, Fig. 10, shows another and very similar finning arrangement for a four-valve head; and Fig. 11 of the R.A.E. 19T shows a method of finning a four-valve spherical-head cylinder. It is exceedingly difficult to fin this latter type of cylinder-head successfully. The finning of side-valve cylinders is shown by the R.A.E. 4A and 4C cylinders, illustrated in Figs. 12 and 13.

For aircraft cylinder-heads the cast fin appears to be the most logical. For automobile or motorcycle-engine cylinders the cast fin is undoubtedly the cheapest and the power output obtained does not justify the use of fins produced by machining or casting-in. On aircraft-engine cylinder barrels machined fins can be used on account of the reduced weight.

Types of Cylinder Head

In general the work on which this paper is based shows that the flat head does not compare favorably, as regards either power output or cooling efficiency, with the spherical or roof types. The reasons for this are plain in my opinion. In the first place, the flat head renders it difficult to maintain the required air-spaces between the valve ports and the necessary metal sections between the valve-seats without reducing the valve sizes excessively. Large air-spaces between the inlet and exhaust-valve ports are desirable with three or four-valve designs employing a pair of exhaust-valves, and it is essential to have a minimum air-space of 3/4 in. between the adjacent exhaust-port walls in such types. Further, with aluminum heads, it is necessary to maintain approximately 5/8 in. as a minimum section of aluminum between adjacent exhaust-valve seat-inserts; otherwise overheating, distortion and cracking will be apt to occur. It is not wise to reduce this section much between pairs of inlet seats or between adjacent exhaust and inlet seat-inserts. An example of flat-head cylinder is shown in Fig. 14, which is an assembly drawing of the Type I engineering division cylinder. This is of 5⅝-in. bore by 6½-in. stroke and is fitted with two 1½-in. exhaust-valves and one 2-5/16-in. inlet-valve. The Type I cylinder is undoubtedly undervalved, but in this case that is the lesser evil.

As an example of the possibilities of valving four-valve flat and roof-type cylinder-heads, the D, F and H types are of interest. All are of 5½-in. bore by 6½-in. stroke and are fitted with four valves of 1⅝-in. diameter in the port. In the first two types the valves are necessarily crowded, with the result that there is insufficient air-space between the exhaust ports and not enough metal between the valve-seat inserts. On test these types of cylinder overheated, gave a relatively low output with a high fuel-consumption and trouble with cracking of the head metal between the valve-seat inserts was experienced. The Type H cylinder illustrated in Fig. 10 allows a ⅞-in. minimum air-space and metal section between the exhaust-port walls and the adjacent exhaust-valve seat-inserts.

With a flat head the walls of adjacent ports do not diverge as much from each other as with roof or spherical heads and thus the area of the total air-space between the ports is less. The included angle between the entrance and the exit of the ports is nearly always smaller with flat heads than with roof or spherical types. With the latter it is nearly always possible to maintain the included angle at more than 90 deg., which is of considerable importance, at least for the exhaust-ports, as there is thus less gas friction and therefore less heat given to the port walls. With an exhaust-port included angle of less than 90 deg. it is easier to avoid choking the port while maintaining good valve-stem cooling by a heavy valve-guide boss and, further, the port walls diverge more sharply from the combustion-chamber wall. Even if the included angle of the port be 90 deg., a greater divergence between the port walls and the cylinder crown is obtained with the spherical or roof type heads, which is of importance for cooling, as the air is thus more uniformly in contact with the metal surrounding the valve-seat.

For efficient cooling it is desirable that the fins be, as nearly as possible, normal to the surfaces to be cooled. This condition is anything but fulfilled by the Type I cylinder. Consider the heat given to the head at the point X in Fig. 15. This heat is partially dissipated to the cooling air at X, but as the capacity of the surface is obviously limited in this respect, the remainder of the heat must be conducted by the head metal to the fins on the cylindrical portion of the combustion-chamber, or to the ports and thence up the port walls to the port finning. The conditions of heat-flow from any point of the combustion-chamber wall to the fins are markedly more direct in the Types H and J cylinders than in any of the flat-head types shown.

The discharge of an inclined valve in a spherical or roof head appears to be much less disturbed and more likely to promote and maintain turbulence than that of a similar valve in a flat head. The flat head is more liable to deflect under explosion pressure and, in practice, breathing of flat heads is by no means unknown. The truly hemispherical head is the ideal form as regards minimum stress due to explosion pressure.

For two-valve designs the spherical head appears to be the most suitable. For four-valve heads the spherical head is undoubtedly the most efficient, but, except for very special cases, its use does not appear to be justified, owing to the manifest difficulties of valve operation and also to the fact that excellent results are obtainable from a suitably designed roof head. When, however, very large cylinders are required, or medium-size designs, either of large bore-stroke ratio or to run at such high speeds that sufficient valving in conjunction with good cooling cannot be obtained with a roof head, there is little question that the spherical head is the most suitable design. An excellent example of four-valve spherical-head design is seen in the R.A.E. 19T cylinder, Fig. 11.

Experience to date indicates that for aircraft-engine cylinders of up to about 170 cu. in. capacity and with bore-stroke ratios not exceeding 1.25 to 1, designed for normal speeds of up to 1800 r.p.m., the roof head will produce the best all-around results. The design of an efficient roof-head cylinder is a tricky proceeding, slight faults in detail being liable to result in poor cooling.

Cooling Surface

The cooling surface obtainable with the type of circumferential-fin cylinder mainly dealt with in this paper will vary between 0.20 and 0.35 sq. ft. per b. hp., the former figure being obtainable on a cylinder of approximately 170 cu. in. capacity and the latter with a design of approximately 70 cu. in. Considering fins of constant length and pitch and a given type of cylinder design, it

TABLE 5—EFFECT OF DIFFERENT COMPRESSION-RATIOS ON THE PERFORMANCE OF AN R. A. E. 4D AIR-COOLED CYLINDER

Compression-Ratio	4.6	5.0	5.4	5.8	6.2[a]	6.4[b]
Brake Mean Effective Pressure, lb. per sq. in.	116.2	119.3	122.0	125.0	129.0	123.0
Fuel-Consumption, lb. per b. hp-hr.	0.530	0.507	0.490	0.475	0.480	0.520
Mean Temperature of Top of Cylinder, deg. fahr.	356	338	315	309	372	414
Mean Temperature of Bottom of Cylinder, deg. fahr.	222	203	192	185	231	275

[a] Occasional detonation occurred with this ratio.
[b] Heavy detonation was noticed when operating with this ratio.

is obvious that the output will increase as the cube of the scale, assuming constant brake mean effective pressure and speed, whereas the cooling surface will increase only as the square. The term cooling-surface includes the fin, barrel, port and head areas. As the average heat-dissipation is approximately 25 B.t.u. per b. hp. per min., the mean heat-dissipation will vary from approximately 70 to 125 B.t.u. per sq. ft. per min.

Owing to the reduction in cooling surface per brake horsepower with an increase of size, it is to be expected that the cylinder-wall temperatures will increase and that higher blast-velocities will be required. In practice it is found that the greater the cylinder size, the higher the permissible maximum and mean wall-temperature, this being probably due to the reduction in the surface-volume ratio of the combustion-chamber in the larger sizes. The minimum blast-velocity to produce the best results varies markedly with size, a 70-cu. in. cylinder requiring approximately 60 m.p.h. and a 170-cu. in. cylinder about 90 m.p.h.

Areas of 0.20 to 0.35 sq. ft. per b. hp. only suffice for efficient operation of overhead-valve designs. L and T-head types require in general an increase of the cooling surface, the cooling air-supply and internal cooling by fuel evaporation, resulting from the use of a rich mixture.

Effect of Compression-Ratio on Output, Fuel-Consumption and Wall-Temperature

The effect of compression on the performance of an air-cooled cylinder is considerable. Results of tests on an R.A.E. 4D cylinder of 100-mm. (3.94-in.) bore and 140-mm. (5.51-in.) stroke, illustrated in Fig. 16, with compression-ratios varying from 4.6 to 6.4 to 1, are presented in Table 5. It will be noticed that the 5.8 to 1 ratio produced the minimum fuel-consumption and wall-temperature and 97 per cent of maximum power. An increase in the ratio to 6.2 to 1 produced the maximum output with a slight increase in the fuel-consumption and a marked increase of wall temperature. These tests were carried

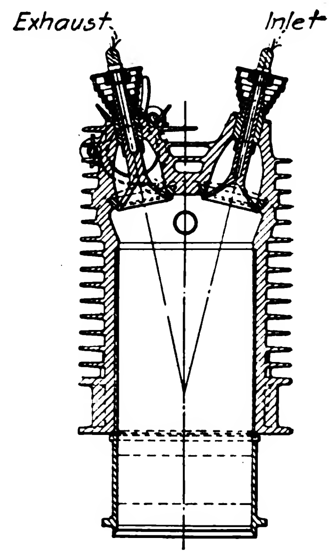


Fig. 16—Exterior View and Sectional Elevation of the 4D Cylinder Developed by the Royal Aircraft Establishment

out with straight aviation gasoline. The effect of cylinder design upon the possible usable compression-ratio is very marked, and it was the cumulative effect of small detail improvements in the head, barrel and exhaust-valve cooling, resulting from the British investigations of air-cooling, that allowed a progressive increase in the possible compression-ratio and an increase of specific output. It can be seen from Table 5 that relatively high compression is of considerable advantage for air-cooling. It is not likely that any further considerable increase of the possible compression-ratio with present aircraft fuel can be secured by any improvement in the design. It is probable, however, that the use of fuel dopes will render possible a further considerable increase. This has been investigated on small air-cooled aircraft-engine cylinders and medium-size water-cooled aircraft engines; the results have shown a considerable increase in the brake mean effective pressure. Should the proportionate increase of performance prove as large with 160-cu. in. air-cooled cylinders as has been found with the 70-cu. in. types, some rather remarkable performances are likely to be produced in the near future.

Cylinder Materials

Some of the materials that have been used for air-cooled cylinder construction are shown with their respective specific gravities and conductivities in Table 6.

On the basis of the conductivity-specific gravity ratio, aluminum appears to be the most logical material for aircraft-engine cylinder construction, as the weight of material necessary to handle the heat-flow becomes out of the question for aircraft purposes with other materials. The development of other light alloys, such as the magnesium group, may eliminate aluminum in the future, but at present it is the most important cylinder material.

Leaving weight out of consideration, conductivity is not the only guide as to the thermal suitability of a material for air-cooled cylinder construction. Some tests confirming this view were carried out by Dr. A. H. Gibson on a R.A.E. 4D cylinder. This cylinder, which is illustrated in Fig. 16, was designed with a cast aluminum head and jacket and fitted with a shrunk-in steel liner. Castings of the head and jacket were made from the same pattern, in aluminum, cast iron, and bronze, all being fitted with similar steel liners. The aluminum cylinder produced the best results, the cast-iron cylinder

TABLE 6—PROPERTIES OF VARIOUS CYLINDER MATERIALS

Material	Conductivity Average Value, C. G. S. Units	Specific Gravity	Ratio of Conductivity to Specific Gravity
Aluminum Alloy	0.40[c]	2.77	0.1440
Forged Steel	0.11[d]	7.80	0.0141
Cast Iron	0.11[d]	7.10	0.0156
Copper	0.89[d]	8.90	0.1000
Bronze (90 per cent Copper and 10 per cent Tin)	0.60[e]	8.78	0.0680

[c] See report on the Materials of Construction Used in Aircraft and Aircraft Engines, by Lieut.-Col. C. F. Jenkin, published by His Majesty's Stationery Office, London.
[d] See Smithsonian Physical Tables.
[e] See Ohio State University Engineering Experiment Station Bulletin No. 20.

developed an equal mean effective pressure with little or no increase in the cylinder temperature on a 10-per cent higher specific fuel-consumption and the bronze cylinder proved inferior to both the cast-iron and the aluminum, developing excessive temperatures. Standard heat-dissipation tests in a wind-tunnel on the bronze cylinder showed that the surface heat-dissipation from the bronze to the cooling air was much inferior to that of either aluminum or cast iron.

Bronze cylinders have been tried by several firms. Although no definite results are known, it is significant that the experiments have not been continued. The inferior surface heat-dissipation of bronze in comparison with steel has been experienced by several spark-plug manufacturers in the course of their experiments with bronze plug-bodies.

Investigation[3] has shown that a steel surface gives 5 to 10 per cent greater heat-dissipation than either aluminum or copper. The dissipation of aluminum, however, is improved about 10 per cent by coating with a glossy black enamel, the percentage of improvement varying with the nature of the enamel and the blast velocity. The effect of surface dissipation is of considerable importance and further investigation of the subject is to be made by the Bureau of Standards and the engineering division.

The principal alloy that has been used by the British for air-cooled cylinder construction is the Air Ministry 2-L-11 alloy, containing 7 per cent of copper, 1 per cent of tin and 92 per cent of aluminum. This was developed after failure had attended efforts to use the aluminum-zinc group, employed so largely on the Continent for crankcases and similar parts. This alloy is both weak and soft when hot, but its bad qualities are, nevertheless, fairly well understood as a result of considerable experience. It sand-casts relatively well; the tin-content, which reduces the strength and hardness, also seems to reduce shrinkage and pin-holing.

An alloy, known as the Y-alloy, developed by Dr. Walter Rosenhain at the National Physical Laboratory, contains 4 per cent of copper, 2 per cent of nickel and 1½ per cent of magnesium.[4] This maintains its strength and hardness at high temperature much better than the 2-L-11 alloy and has been used to a limited extent for cylinder castings. It appears to have great possibilities for air-cooled cylinder construction, principally on account of its hot strength and hardness, but much will depend on its ease of casting, of which I have no knowledge. For air-cooled seaplane engines it is possible that this alloy may prove distinctly advantageous, owing to its remarkable resistance to corrosion by sea water.

The silicon-copper-aluminum alloys appear to be one of the most promising groups yet tried for cylinder construction and at present the only unknown factor concerning the group is its conductivity. It seems that this group, which at present is under development by the engineering division and others, will mark a distinct forward step in alloys for air-cooled cylinders. Its freedom from cracking, porosity and shrinkage appear to go far toward eliminating the troubles of the commercial production of aluminum air-cooled cylinder castings. An important advantage of this alloy is that chills, which in production with jolt-ram molding machines by unskilled labor are exceedingly objectionable, can be entirely eliminated.

[3] See *Proceedings of the Institution of Automobile Engineers*, vol. 14, p. 243.

[4] See the 11th Report of the Alloys Research Committee of the Institution of Mechanical Engineers.

[5] See *Automotive Industries*, Sept. 8, 1921, p. 474.

Some particulars of the casting of silicon alloys for air-cooled cylinders have already been published,[5] and it is hoped that the results of the further investigations of the materials section of the engineering division will be published in the near future. The silicon-copper alloy, containing 4 per cent of silicon and 3 per cent of copper, possesses considerable ductility, which is of some practical importance as bent fins and the like made of it can be straightened without danger. Most of the silicon-alloy cylinders produced by the engineering division have been cast in this alloy and have proved somewhat difficult to machine. Threading has given most trouble in this respect, owing to the tearing of the metal and the wear of the tools. The machining properties are, however, likely to be much improved by the investigations now being conducted. The silicon-copper alloy presents an excellent example of the danger of judging alloys for cylinder construction by test-bar results alone. From the test-bar results little consideration of the silicon-copper alloys and less of the 2-L-11 alloy would be justified, though both have proved excellent. Test-bar results entirely fail to show casting properties, an aspect of marked importance for air-cooled cylinder production.

Alloys containing copper and manganese which have a constant or an increasing strength up to 500 deg. fahr., have been tried for air-cooled cylinder castings. Owing principally to casting difficulties they have been dropped in favor of more promising groups. The conductivity of alloys containing manganese is fully developed only after annealing. In some cases the increase of conductivity due to annealing amounts to as much as 40 per cent. Most alloys show a somewhat improved conductivity after annealing. Apart from this effect, annealing is very necessary to remove growth and casting strains. If cylinder-heads are not annealed, growth and distortion develop rapidly in the course of engine operation. With an unannealed screwed-on head the effect of growth is most serious; such a head will become loose on the cylinder barrel in 10 to 20 hr. running. Growth due to lack of annealing further results in valve-seat inserts, valve guides and cylinder studs becoming loose in the casting.

The physical properties of some aluminum alloys used for cylinder castings are shown in Table 7.

TABLE 7—PHYSICAL PROPERTIES OF ALUMINUM ALLOYS EMPLOYED FOR SAND-CAST CYLINDERS

Alloy	2-L-11[f]	Y[g]	Copper Silicon[h]
Composition	Cu 7% Sn 1%	Cu 4% Ni 2% Mg 1½%	Si 4% Cu 3%
Tensile-Strength, lb. per sq. in.			
60 Deg. Fahr.	14,800	24,400	21,400
300 Deg. Fahr.	12,300	23,800	19,400
600 Deg. Fahr.	8,300	23,000	11,800
Brinell Hardness Number			
60 Deg. Fahr.	55	71	50
300 Deg. Fahr.	54	68	..
600 Deg. Fahr.	25	46	..

[f] See report on the Materials of Construction Used in Aircraft and Aircraft Engines, by Lieut.-Col. C. F. Jenkin, published by His Majesty's Stationery Office, London.

[g] See the 11th Report of the Alloys Research Committee of the Institution of Mechanical Engineers.

[h] From tests made by the materials section of the engineering division of the Air Service.

For cast-aluminum cylinders a fin having a length of from 1 to 1⅛ in., a thickness at the root of ⅛ in., a thickness at the tip of 1/16 in. and a ⅜-in. pitch, is fairly readily cast and is reasonably strong for handling. Fins of a somewhat decreased thickness and pitch can

FIG. 17—HEAD CASTINGS, READING FROM LEFT TO RIGHT, FOR THE TYPES H, I AND J AIR-COOLED CYLINDERS

TABLE 8—TYPICAL ANALYSIS OF BRITISH AIR-COOLED AIRCRAFT CYLINDER IRON

	Minimum	Maximum
Combined Carbon, per cent	0.50	0.80
Total Carbon, per cent	2.70	3.50
Silicon, per cent	1.20	2.00
Sulphur, per cent	....	0.12
Phosphorus, per cent	...	0.80
Manganese, per cent	0.50	1.20

be cast, but are likely to lead to foundry difficulties and are easily damaged.

The photographs of the Types H, I and J heads, reproduced in Fig. 17, from left to right in the order named, show some excellent castings. It may be mentioned that fins were sand-blasted after little or no dressing.

Cast iron at present is somewhat despised as a cylinder material. Nevertheless, it can be seen from the B.S.A. and R.A.E. 4D cylinders mentioned earlier in the paper that efficient results are obtainable with this material. I believe that for commercial purposes, excepting aircraft engines, the use of any other material than cast iron for cylinder construction is not justified by the increased efficiency obtained. The use of any more expensive material than cast iron also involves more complicated and expensive construction. In the light of present experience that statement appears to hold good up to an output of 12 hp. per cylinder at about 2500 r.p.m.

A comparison of the weight of the cylinder-body proper, excluding the valves and the valve-gear, obtainable with heavy cast-iron construction and by the use of advanced aircraft-engine design, with the weight reduced to a minimum, may be of interest. A cast-iron cylinder of massive proportions, with little liability to breakage that will give excellent cooling, will weigh 2 lb. per hp. for a high-speed engine using European fuel, and probably 3 lb. per hp. for a medium-speed engine using domestic fuel. The most efficient aircraft practice does not result in cylinder-body weights of much less than 0.4 lb. per hp. when operating at a lower speed, but using compression-ratios that are impossible for car practice and fuels that are not at present available for commercial work. This class of construction calls for expensive machining hardly desirable or necessary for a car engine. Further, aircraft design in the small bores required for car work becomes somewhat fragile and easily liable to damage in handling. In any case the resultant saving in weight when using aircraft construction for a 50-b. hp. engine would be only 130 lb. and this could be removed to better commercial advantage from some other portion of the engine or chassis.

Semi-steel is practically never used for cylinder castings in Great Britain. A typical analysis of British air-cooled aircraft-cylinder iron is shown in Table 8.

An interesting sidelight on cast iron as a cylinder material is seen in Table 9 which is taken from a British report on the materials of construction used in aircraft and aircraft engines. The 20-per cent increase in the conductivity after annealing possibly explains why cast-iron cylinders of very light section rarely perform as well when new as after considerable service. It is the prac-

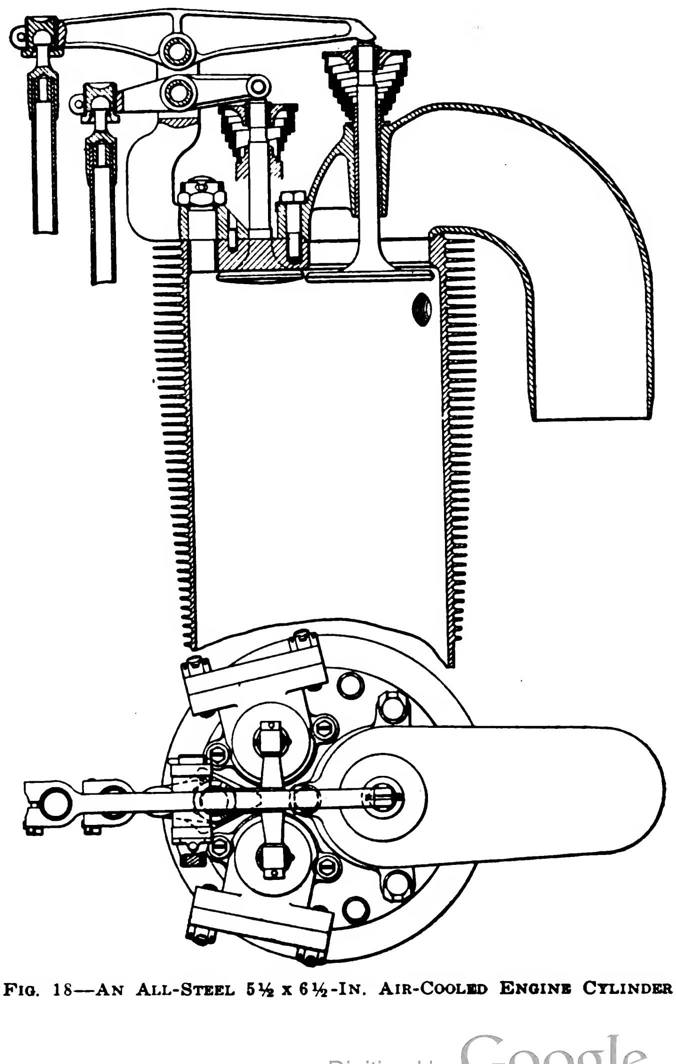


FIG. 18—AN ALL-STEEL 5½ x 6½-IN. AIR-COOLED ENGINE CYLINDER

TABLE 9—ANALYSIS OF A CYLINDER IRON

	As Cast	Annealed
Graphitic Carbon, per cent	2.640	3.340
Combined Carbon, per cent	0.850	0.150
Silicon, per cent	1.840	1.940
Sulphur, per cent	0.078	1.090
Phosphorus, per cent	1.090	1.090
Manganese, per cent	0.820	0.850
Conductivity at 212 deg. fahr., in C. G. S. units	0.102	0.121

tice of several Continental motorcycle companies to run-in engines on the test-block for protracted periods without a cooling blast. Many racing motorcyclists subject their engines to a continual violent overheating before attempting to use them for racing. The improvement due to preliminary overheating generally has been attributed to the release of the casting strains and to seasoning. It is, however, more likely that the increase in the conductivity has the greatest influence on the improvement in performance.

Cast-iron cylinders often have poorly proportioned fins. Excessively long and very thin fins of the extreme proportions the foundries can produce are commonly used. In general fins longer than 1 in. are not good. The low conductivity of cast iron prevents the tip of a long thin fin from being of much practical use. Long thin fins are exceedingly fragile and very liable to damage in handling, in addition to being difficult to cast. In many Continental motorcycle factories the scrap resulting from the handling of cylinders with long thin fins is large. An all-around efficient fin for cast-iron cylinders as regards strength, ease of foundry production and cooling should have a length of 1 in., a pitch of 3/8 in., a root thickness of 9/64 in. and a thickness at the tip of 5/64 in. A fin of these proportions will stand very rough usage without breakage.

Copper has been used extensively for air-cooled cylinders and was employed on some of the earliest air-cooled cars. The high conductivity is of considerable advantage, but there are many practical objections to its use. One of these is that it is exceedingly difficult to fin a cylinder-head efficiently with sheet-copper fins. To attach the latter to a spherical head such as the Type J cylinder is almost out of the question and in any case entails the use of a heavy iron casting for the body of the head. Some copper air-cooled aircraft-engine cylinders were produced in Great Britain during the war. These had a closed-end steel barrel fitted with sheet-copper circumferential fins, head cooling being attempted by a finned cast-aluminum cap. The performance compared unfavorably with that of the composite aluminum and steel type with cast-on or screwed-on heads. The economical use on a weight basis of copper as a fin material requires the use of thin sheet, and such fins are readily bent and damaged. The copper-finned cylinders previously referred to presented an extremely ragged appearance after a short period in service, as handling was sufficient to bend the fins.

Cast copper can be used as a head material, but it is exceedingly difficult to cast, as is evident from the troubles with pure copper castings in the electrical industries. Cast-copper heads are moreover unsuitable for aircraft purposes owing to their excessive weight.

Sheet-copper finning can be used for barrel cooling of a cylinder of the type shown in Fig. 18, no attempt being made to fin or cool directly the crown of the head. Such design has, however, proved unsound.

Steel has been used to some extent for stationary-engine cylinders and is practically universal for rotary-engine cylinders. Usually steel cylinders are machined from solid billets or drawn shells. Practical machining difficulties interfere with the production of any efficiently finned form of cylinder-head, except as regards monosoupape types. The two-valve rotary-engine cylinder, with all its complicated machining on the head fins, gives poor results when operated as a stationary cylinder.

The general design of steel cylinder has had circumferential fins on the barrel, a thick integral flat head entirely without finning, with the inlet and exhaust-ports bolted on. A typical type of this design is shown in Fig. 18. Cylinders of this type have shown a relatively low mean effective pressure and a high fuel-consumption, in conjunction with excessive wall-temperatures.

For the composite aluminum and steel aircraft cylinder, the integral-fin open-ended steel barrel gives excellent results. The high strength allows of thin wall-sections and thin fins that are capable of dealing with the relatively mild thermal conditions existing on the barrel.

No consideration of bronze as a material for cylinder-heads or complete cylinders is warranted; it has been mentioned elsewhere that unsatisfactory results are obtained in spite of the high conductivity of the material. Bronze shrunk-in liners have been tried with aluminum cylinders and given better results thermally than steel, but rapid wear of the bore developed.

It is the practice of the engineering division to use an extruded aluminum-bronze, containing 90 per cent of copper and 10 per cent of aluminum, for expanded or shrunk-in valve-seat inserts and spark-plug bushings in aluminum cylinder-heads. For these purposes this material has given excellent results. It has a relatively high coefficient of thermal expansion, from 75 to 90 per cent of that of an aluminum alloy and the strength and the hardness are not seriously reduced at operating temperatures. Aluminum-bronze rapidly hammer-hardens on the face of a valve-seat insert, producing a mirror-like hard surface that is extremely resistant to abrasion and erosion.

Extruded aluminum-bronze is used also for studs in aluminum heads and largely eliminates the trouble of the studs unscrewing when hot, so frequently experienced with those made of steel. The burning-on of nuts to the studs is also eliminated. Aluminum-bronze can be used safely to replace steel studs carrying impact loads, as it has a remarkable resistance to alternating and impact stresses.

In general, it appears that the conductivity of the cylinder-wall is of more importance than the conductivity of the fin itself. Cast fins, for production reasons at any rate, usually have to be made considerably thicker than is necessary purely from heat-flow considerations. In practice it has been found that increasing the wall thickness improves the performance. No case has yet been found with the type of cylinder investigated where the walls have proved too thick. An increase in the conductivity of the metal of the wall is equivalent to an increased thickness in a metal of lesser conductivity.

To avoid distortion it is desirable to aim as far as possible at a symmetrical design laid out so that temperature or casting stresses will be minimum. The cylinder material, whatever it may be, should be in such condition and of such type that a minimum of distortion will develop in service. The theory that distortion is synonymous with overheating was accepted at one time by many in Europe. It is, however, far from being true. For instance, the Airco cylinder overheated when tested with an inlet-side blast, as is brought out in Table 3, but it did not distort; the R.A.E. 4A cylinder, although kept cool by an excessive fuel-supply, was always more or less distorted.

Types of Cylinder

Neither the L nor the T-head cylinder is worthy of much notice at this date. In my opinion a good side-valve cylinder, for either aircraft or automobile use, is decidedly superior to a crude overhead-valve design. In spite of years of effort the number of really efficient air-cooled side-valve cylinder designs in existence is prob-

ably under a dozen. Such efficient designs as exist are the result of protracted experiment; an overhead-valve design to produce equal or superior results can be produced readily with practically no development.

The side-valve cylinder has marked disadvantages in comparison with the overhead type. Combustion-chamber areas are relatively greater, equally efficient finning cannot be obtained, the temperature distribution is perforce much more uneven and distortion is much more likely to occur. Distortion is exceedingly difficult to avoid in side-valve cylinders. The inlet and exhaust ports usually distort the barrel, with the result that piston contact is poor and the ring fit uneven. The valve-seats rarely remain true when hot, with the result that grinding-in the valves with the cylinder hot is resorted to at times.

The side-valve design of necessity departs from the symmetry so desirable for an air-cooled cylinder. For equal class of design and development, the mean effective pressure of a side-valve cylinder is usually 20 per cent less than that obtainable from an overhead-valve type, with continuous full-throttle operation. A comparison of cylinders of equal size which is contained in the Internal-Combustion Engine Subcommittee of the British Advisory Committee for Aeronautics Report No. 24 gives, in my opinion, an average figure for the relative efficiencies of overhead and side-valve types.

The R.A.E. 4A cylinder, a thin cast-iron L-head type, illustrated in Fig. 12, of 100-mm. (3.94-in.) bore and 140-mm. (5.51-in.) stroke, with an overhead exhaust-valve directly over an inlet-valve fitted in a detachable cage, developed 85-lb. per sq. in. brake mean effective pressure at 1800 r.p.m. with a fuel-consumption of 0.67 lb. per b. hp-hr. The R.A.E. 4C cylinder had a similar valve arrangement to that of the R.A.E. 4A, but had a cast-aluminum head and jacket, the head and the jacket only being shown in Fig. 13, with a shrunk-in steel liner. This design developed 85-lb. per sq. in. brake mean effective pressure at 1800 r.p.m., with a fuel-consumption of 0.57 lb. per b. hp-hr., a reduction in consumption of 15 per cent in comparison with the R.A.E. 4A cylinder. The R.A.E. 4D cylinder, illustrated at the left of Fig. 16, had a cast-aluminum head and jacket and a shrunk-in steel liner and was fitted with two inclined overhead-valves. At an early stage of its development this design gave 115-lb. per sq. in. brake mean effective pressure at 1800 r.p.m., on a fuel consumption of 0.475 lb. per b. hp-hr., with a 4.7 compression-ratio. At a later stage with a 5.5 compression-ratio over 130-lb. per sq. in. brake mean effective pressure was obtained. In comparison with the R.A.E. 4C the R.A.E. 4D developed a 35-per cent higher brake mean effective pressure on a 17-per cent lower fuel-consumption.

Some of the pros and cons of the various types of overhead-valve composite aluminum and steel aircraft-engine cylinder construction are considered below. The head cast on an integral-fin steel barrel possesses the advantages that

(1) No machine-shop operations are required to fit the head to the barrel
(2) It produces probably the lightest possible design

Fig. 19 shows a cast-on head that failed in service; although the cylinder illustrated is of poor design, even the most highly developed types have not been immune from this trouble. The disadvantages of this type are that

(1) Very high casting stresses are set up in the head, which are liable to cause failure in service and cannot safely be removed by annealing, as this would largely remove the shrink of the head on the barrel
(2) The alloy in the head casting is in a state of instability owing to the lack of annealing
(3) It is next to impossible to inspect the condition of the contact of the head with the barrel
(4) Foundry difficulties are numerous; although in times of peace they can be overcome, the great care and supervision required are unsuitable for the stress of war time. The finished casting represents but a very small percentage of the weight of the metal melted to produce it
(5) Barrel production has to start before that of the heads and the complete cylinders
(6) Removal of an unsound head casting from a barrel may scrap the latter
(7) Damaged heads or barrels cannot be removed from one another in the field and new parts fitted to the sound portion
(8) The finned steel barrel is somewhat expensive to produce and wastes a lot of material
(9) Fitting of expanded or shrunk-in valve-seats is a poor production job with tilted valves
(10) If a roof-type head be adopted, machining is difficult

FIG. 19—A 5⅞ x 6-IN. ALUMINUM CYLINDER
The View at the Left Is a Side View of the Cylinder and Shows the Fracture That Occurred When the Cast-On Head Was Blown Off. The Illustration at the Right Is a View Looking Directly at the Bottom of the Blown Off Cylinder-Head

The advantages of the bolted-on head are

(1) Ease of production and assembly
(2) Ease of replacement of damaged parts

This type of head possesses the disadvantages of

(1) Difficulty of maintaining pressure tightness at the joint between the head and the barrel; if any flame gets through, the head is burned out
(2) Axial heat-flow from the head to the barrel is practically non-existent. The cooling efficiency is reduced and as a result head temperatures and fuel-consumptions are increased

The points in favor of a screwed-on head are

(1) Good production proposition in the foundry, with less remelting of runners and waste metal than is necessary with cast-on types
(2) Contact between the barrel and the head is under control and inspection
(3) Alloy is in a condition of stability and highest conductivity owing to annealing
(4) Casting stresses are eliminated and replaced by a less severe and constant stress due to shrinking

FIG. 20—SECTION OF AN ALUMINUM JACKET CAST ON TO THE CYLINDER LINING SHOWING THE POOR CONTACT BETWEEN THE TWO

(5) Machining of the ports, the inside of the head and the valve-seats and expanding or shrinking-in of the last, if thus fitted, is accessible

(6) Barrel and head production start together and are concurrent

(7) Unsound head castings do not involve damage to the barrel

(8) Damaged liners can be replaced with ease in field workshops

Opposed to the foregoing advantages are the following

(1) The finned steel barrel is expensive to produce and wastes material. Further, the threads on the barrel and in the head have to be held to close tolerances

(2) A fair amount of machine work has to be done on the barrel after it has been shrunk into the head, aside from the grinding out of the bore. As the starting point of the thread in the head and on the barrel cannot be controlled, barrels have to have location points and possibly holding-down bolt-holes machined after the head is shrunk-on. This means that a good head can be refitted upon a new barrel, but a defective head on a sound barrel cannot be replaced

The construction in which the jacket and the head are cast on the liner is favored because

(1) The liner can be produced from a thin tube, wastes little material and is cheap to produce in the machine-shop

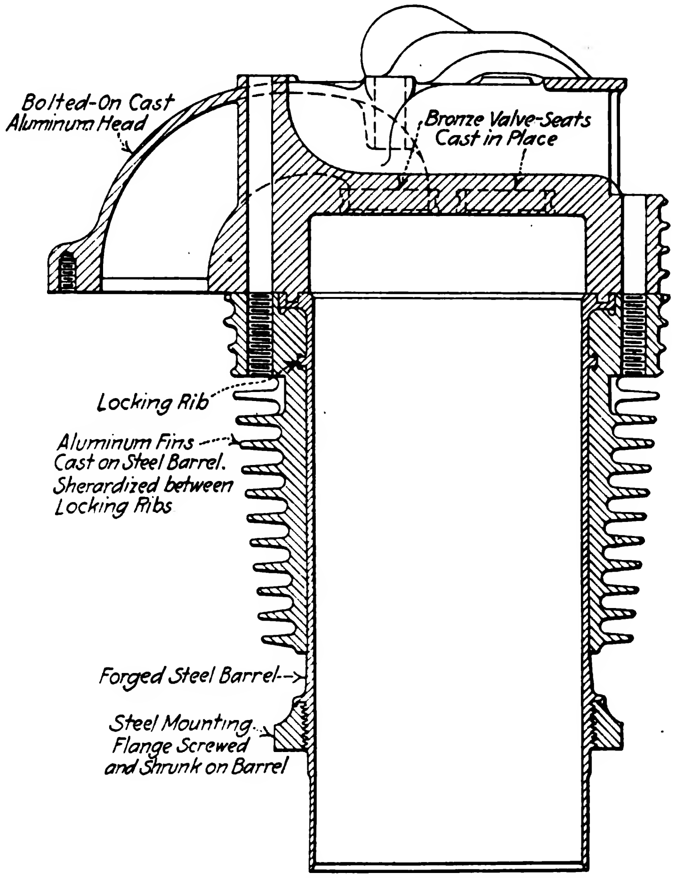


FIG. 21—THE TYPE F 5½ X 6-IN. CYLINDER DEVELOPED BY THE ENGINEERING DIVISION OF THE AIR SERVICE

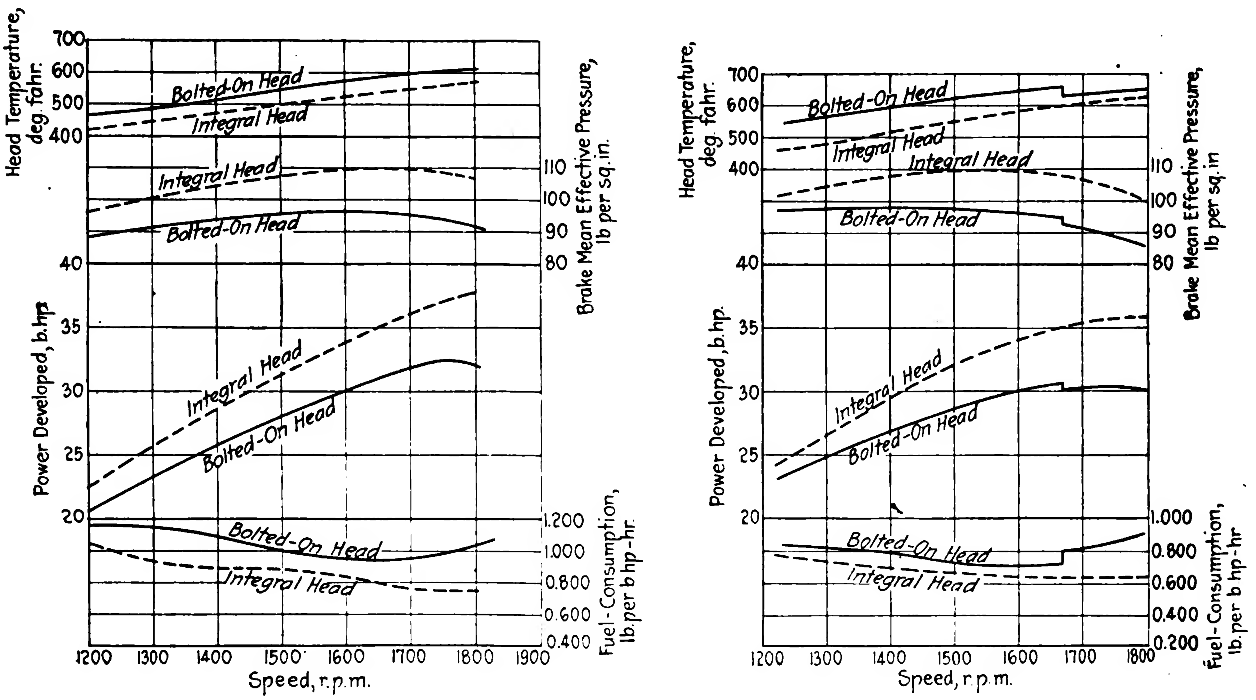


FIG. 22—CHARTS SHOWING THE COMPARATIVE PERFORMANCE OF THE TYPES D AND F CYLINDERS

(2) Fitting of the head and the jacket is not dependent on machine-shop work

The objections urged against such a design of cylinder are

(1) The state of contact between the casting and the liner is unknown. The contact is often very poor; in some cases as little as 5 per cent of the inside surface of the jacket is in real metal-to-metal contact with the outside of the liner. Fig. 20 shows a portion of the inside surface of a cast-on jacket and clearly indicates the poor contact; this view is representative of this particular design and is not an isolated instance
(2) Sliding contact between jacket and liner is continually occurring and eventually results in attrition as the sliding surfaces are oxidized
(3) All heat delivered from the liner to the jacket has to pass a thermal gap, and a bad one at that, involving two oxide films
(4) It is a poor production proposition in the foundry, having all the difficulties mentioned for cast-on heads, and others in addition
(5) The weight of a steel liner with an aluminum jacket cast or shrunk-on is greater than that of a barrel with integral steel fins

The type of cylinder construction in which the head and the jacket are an integral casting with a shrunk-in liner possesses the advantages that

(1) The liner can be produced from a thin tube and is cheap to machine
(2) The jacket and the head is a good production job in foundry

The following objections are raised to this design of cylinder

(1) The whole explosion load is taken through the jacket, the load being transmitted to four or more bolts. This arrangement requires a heavy jacket and even then is not satisfactory, for aluminum at the temperatures obtained has not proved suitable for the resulting heavy localized stress at the bolt-bosses. The cast-on or screwed-on head types transmit the explosion load from the head to the barrel and thence to the holding-down bolts, with practically uniform stress in the circumference of the head metal
(2) Unless a heavy liner is used, it is difficult to prevent distortion and lack of contact between the liner and the jacket. It is very difficult to prevent oil from leaking between the liner and the jacket, which causes a lack of contact owing to carbonization. Oil leakage, with the resultant carbonization, is much less serious with a screwed-on head than with a shrunk liner, as the fitting surface on a shrunk liner can be covered completely with carbon, whereas the screwed-on head carbonizes only on the unloaded faces of the threads
(3) To eliminate oil leakage as far as possible the joint of the liner with the jacket should be made at the liner top. Owing to the difference in coefficients of expansion of the materials of the liner and the jacket, much ingenuity is required to determine the correct position in which to attach the holding-down bosses to the jacket so that the bolts may be under constant tension. Trouble occurs owing to the jacket deflecting at the holding-down bosses and locally distorting the liner
(4) The increase of weight with this construction is greater than that of the cast-on head and jacket type, owing to all explosion load being transmitted throughout the length of the jacket

The advantages of the steel barrel with an aluminum cap are

(1) The cap is easily fitted
(2) Pressure tightness is not dependent on fit of cap

Opposed to the foregoing advantages are

(1) The closed-end barrel is more expensive to machine than the open-end type used with a cast-on or screwed-on head design
(2) The state of contact of the head is unknown after a little service, and this contact is difficult or impossible to maintain. Flame-blowing between the cap and the top of the barrel has been known to occur
(3) Can only be used for flat heads
(4) Gives a poor performance in comparison with cast-on or screwed-on spherical or roof heads
(5) The valves are seated in the steel head and are guided in the aluminum cap. The difference in the coefficients of expansion of the two parts is liable to cause misalignment of the valves on their seats, contributing to valve burning, warpage and leakage generally characteristic of this construction
(6) Owing to the relative expansion of the cap and the barrel due to the difference in the coefficients of expansion of the materials, either sliding must occur between the two contact faces or heavy stresses be set up in the cap and the bolts attaching it to the barrel

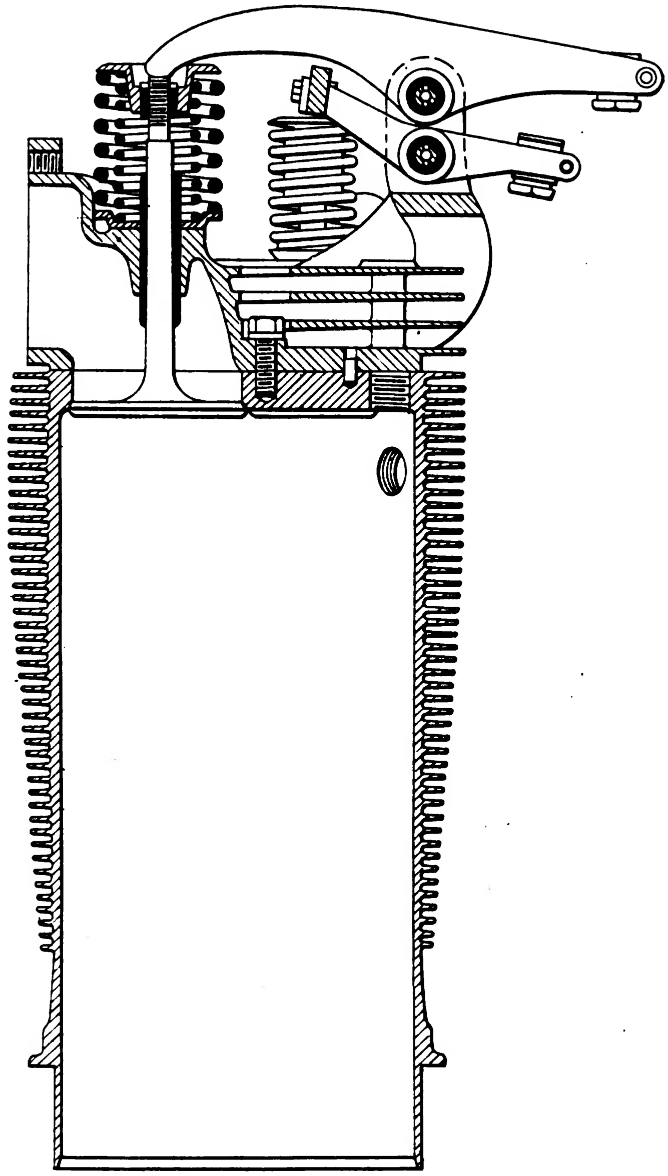


FIG. 23—SECTIONAL ELEVATION OF A $5\frac{1}{2}$ X $6\frac{1}{2}$-IN. STEEL CYLINDER WITH AN ALUMINUM CAP

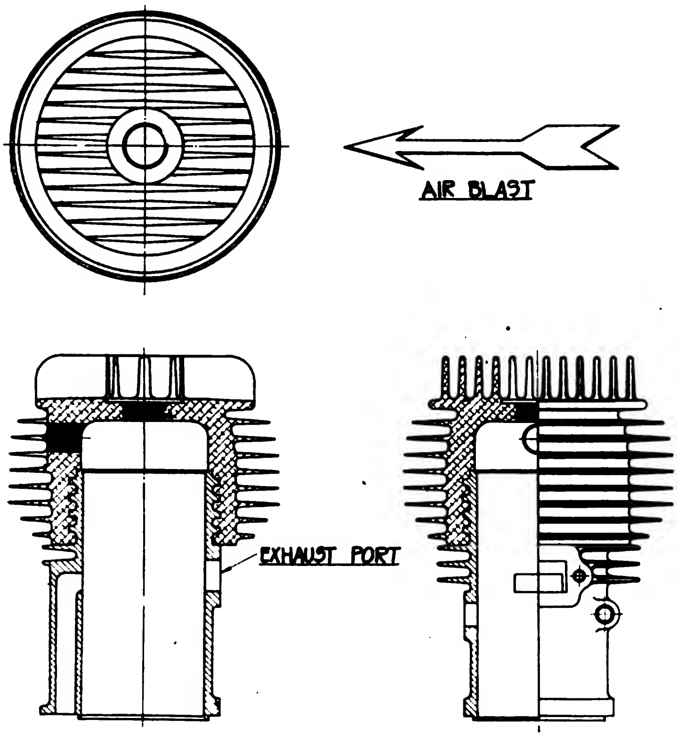


FIG. 24—PLAN VIEW AND SECTIONAL ELEVATION OF A COMPOSITE ALUMINUM AND CAST-IRON TWO-CYCLE CYLINDER

The importance of axial heat-flow from the cylinder-head to the barrel is shown by the following tests conducted by the engineering division. The tests were carried out on two cylinders of identical design, except that one had a detachable bolted-on cast aluminum head and the other a cast-on aluminum head. The Type F detachable head is shown in Fig. 21 and the Type D integral head is illustrated at the left of Fig. 6. The performance of the two designs under identical conditions with both rich and lean carbureter-settings is presented in Fig. 22.

A comparison of the all-steel, the steel barrel with an aluminum cap and the steel barrel with a cast-on spherical aluminum head types will serve to show the merits of the designs. The cylinders were all of 5½-in. bore by 6½-in. stroke and were tested[6] under similar conditions. The steel cylinder, see Fig. 18, had a flat steel head with two cast-iron exhaust ports and one aluminum inlet port bolted-on. The capped cylinder, which is illustrated in Fig. 23, used a barrel of the all-steel type and was fitted with a bolted-on cast-aluminum cap. The cast-on head cylinder shown at the right of Fig. 6, used a barrel similar to the all-steel and capped types, but with the head cut-off and an aluminum head cast-on.

Under maximum-load mixture conditions the capped design developed 13 per cent less power on a 25-per cent higher specific fuel-consumption than the cast-on head type, and the all-steel type developed 13 per cent less power on a 32-per cent higher fuel-consumption than the cast-on type. While the all-steel cylinder was not of the most suitable design for the fitting of a cap, and better results both as regards power output and fuel consumption are obtainable from a cylinder initially designed for a cap, nevertheless, the comparison in general shows the relative value of the three types of design.

Attempts to secure low cylinder-weight per cubic inch of capacity by the use of high-tensile material and thin sections usually result in a cylinder having a rather high weight per brake horsepower developed. Composite aluminum and steel cylinders usually have a higher weight per cubic inch of capacity than the all-steel type; however, the weight per brake horsepower developed for normal cycle types has proved to be considerably lower.

To design a 150-cu. in. cylinder to weigh not over 0.65 lb. per b. hp. requires considerable care; weights as low as 0.55 lb. per b. hp. have been obtained with 70 to 100-cu. in. cylinders. In my opinion a reduction in the cylinder weight per brake horsepower is most likely to be brought about by an increase in the brake mean effective pressure, principally as result of improved fuel, rather than by the use of improved metals. Cylinder weight, as here used, is that of the cylinder complete with valves, valve-gear spark-plugs and push-rods.

TWO-CYCLE CONSTRUCTION

The two-cycle air-cooled cylinder is generally considered to be almost of necessity prone to overheating and some consideration of the type is therefore justified. It is not surprising that the average two-cycle air-cooled cylinder should overheat, as it is usually a very light, thin and poorly finned cast-iron type. However, efficiently cooled cylinders for two-cycle engines are now produced.

The use of aluminum perhaps is justified commercially for two-cycle cylinders for air-cooled motorcycle engines, for the cooling conditions on such engines are usually very arduous. With cast-iron combustion-chamber the carbon deposit is both more adherent and of greater quantity than with one of aluminum. A type of composite aluminum and cast-iron two-cycle motorcycle cylinder is shown in Fig. 24. This was produced by casting an aluminum head on the barrel of the cast-iron cylinder originally fitted to the engine. No exact performance data were ever obtained with this cylinder. However, during 6000 miles of use on the road no mechanical or thermal trouble developed and overheating did not occur at any time, in spite of much use in mountain country. The head was coated with a glossy black enamel that would burn at 550 deg. fahr., and the lack of overheating was borne out by the perfect condition of the enamel at the end of the tests.

Although in general it is poor policy to shunt design difficulties to the foundry by the use of cast-in liners, barrels and the like, there appears to be much justification for the design shown in Fig. 24, as it is, in the main, a simple foundry proposition and well adapted to die-casting. The casting stresses due to the barrel are not complicated by others arising from cast-in seat-inserts or a non-symmetrical layout. The design of head finning is probably the most efficient obtainable for this type of cylinder. The head layout in this case is not suitable for screwing-on. Efficient cooling is probably obtainable from heavy thick-walled cast-iron two-cycle cylinders. This, however, is conjecture, as I have not actually tested such cylinders.

VALVE-SEAT INSERTS IN ALUMINUM CYLINDER-HEADS

Valve-seat inserts are a frequent source of trouble in aluminum cylinder construction. Conditions require an insert that has a tight fit and good thermal contact with the cylinder-head metal when both are hot. The use of cast-iron or steel inserts is not good practice, regardless of how they are fitted, as the coefficients of expansion of cast iron and steel are only 30 and 40 per cent respectively of that of aluminum. Cast-iron or steel inserts if cast-in are very liable to cause blowing of the aluminum surrounding the insert. Aluminum-bronze has, on

[6] See *Proceedings of the Institution of Automobile Engineers*, vol. 14, p. 243.

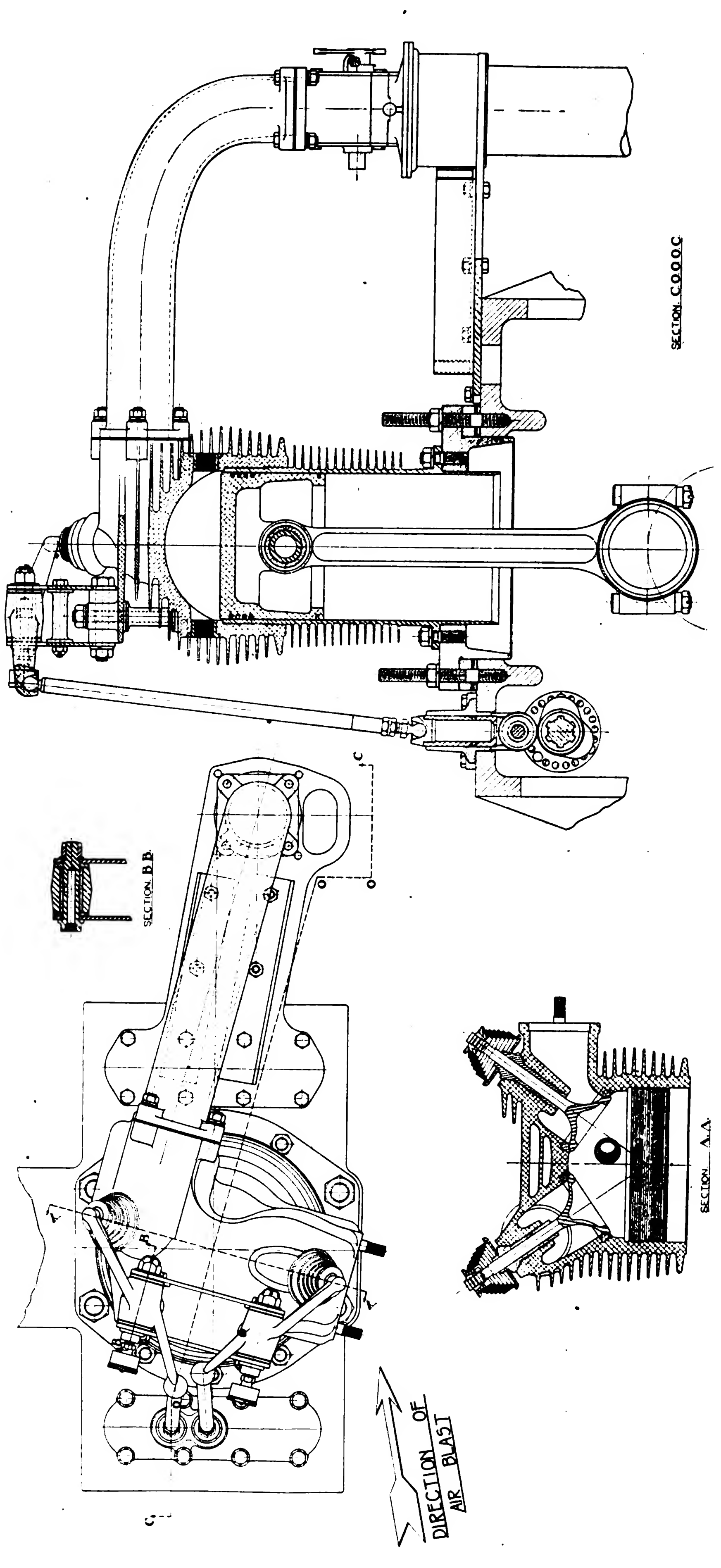


FIG. 25—ASSEMBLY DRAWING OF THE TYPE J AIR-COOLED CYLINDER DEVELOPED BY THE ENGINEERING DIVISION OF THE AIR SERVICE

the whole, proved the most successful for cast-in seat-inserts.

Cast-in inserts are a poor production proposition in the foundry. They are exceedingly liable to shift on the core when in the mold and cause the bore of the insert to be eccentric with the outside when finish-machined. The cast-in insert of any material is prone to develop defective thermal contact or to even come loose. Due to casting shrinkage the insert initially may be tight in the cylinder-head when both the head and the insert are hot. As a result either of annealing in the course of production or of the gradual annealing that occurs in operation the casting shrinkage is ultimately largely removed. The less the difference is in the coefficients of expansion of the materials of the head and the insert, the greater will be the chance of a cast-in insert remaining tight. Aluminum-bronze cast-in inserts have on this account proved markedly superior to steel or cast iron. Cast-in inserts are an example of evading a design issue at the expense of the foundry.

The expanded-in insert gives excellent results in annealed cylinder-heads. The amount of expansion required has, however, to be determined experimentally in each case and is rather difficult to control. Shrunk-in aluminum-bronze inserts have been developed by the engineering division and given excellent results. Shrinking fits and temperatures are much more readily controlled and inspected than either casting-in or expanding. With shrunk seat-inserts the cylinder-head has to be machined partially, the inserts then shrunk in and the head reset for final machining, which is somewhat of a disadvantage. The shrunk insert, at least for inclined valves, is difficult to apply to other than bolted-on or screwed-on heads. It is possible with a shrunk-in insert and with known shrinking allowances and temperature conditions to be certain that good thermal contact always exists.

The greater conductivity of bronze in comparison with cast iron or steel is a distinct advantage for an insert. While the radial effect is of little consequence, the increase of possible circumferential heat-flow within the insert may in some cases have a marked effect on the valve cooling, particularly where two exhaust-valves are used. In three or four-valve cylinders it is often noticeable that the points of closest proximity of the exhaust-valves are considerably hotter than the most widely separated portions.

Exhaust-Valve Cooling

In general, exhaust-valve cooling has two distinct phases, cooling through the seat and cooling via the stem and the guide. If either be at fault, inspection when running on open exhaust will determine which is the offender. For efficient seat-cooling as effected by valve design, I prefer a tulip valve with a thick rim, possessing greater circumferential conductivity than the flat-head valve, and the use of a wide valve-seat. The width of the valve-seat undoubtedly has a marked effect upon the heat-flow from the valve to the cylinder-head, as the intensity of the heat-flow will depend on the area of the valve in contact with the cylinder. The heat-flow from the valve to the cylinder will be affected to some extent by the load of the valve-spring; from this standpoint the greater the load the better. The Type J cylinder exhibits very good seat-cooling, and uses a wide valve-seat, the bore of the exhaust port being 2¼ in. and the top diameter of the seat 2 9/16 in. Valve-seat cooling in this cylinder is as good as obtains in any water-cooled cylinder using a similar valve size and under all running conditions a dead black rim ½ in. wide is shown on the valve.

Efficient stem-cooling is assisted by extending the valve-guide and guide-boss down as closely to the head of the valve as possible, and shrouding the guide with a heavy boss that is able to conduct away the heat abstracted from both the valve-stem and the exhaust gas. The cooling via the valve-stem is partly controlled by the sectional area of the stem and the area of the stem in contact with the guide.

The Type J cylinder is of efficient design as regards conducting the heat away from the exhaust-valve guide; however, the guide-cooling with the valve shown in Fig. 25 has not proved as good as it might be. This cylinder initially had a 7/16-in. diameter exhaust valve stem and this was found to have insufficient area to carry away the heat from the head of the valve and insufficient surface to dissipate the heat from the stem to the guide efficiently. As a result the stem overheated; further, the high-temperature zone extended too far up the stem. An increase in the stem diameter has improved the cooling to some extent. Partially as a result of the stem overheating, trouble has been experienced with breakage.

Claims that the exhaust-valve cooling of air-cooled engines is equally as good as that of water-cooled engines may appear to be an exaggeration. Nevertheless such claims are not merely my personal opinion but can be confirmed readily by the engineering division.

The effect of the mixture-strength on the exhaust-valve temperature is marked, and a reference to Fig. 26 shows that the maximum valve-temperature is obtained with approximately optimum mixture-strength, the temperature diminishing with either a richer or a weaker mixture. With a badly cooled cylinder, however, it is not possible to run on the optimum mixture, as violent overheating of the valve will occur on even considerably richer mixture-strength. The temperatures shown were obtained on an R.A.E. 4E cylinder of 100-mm. (3.94-in.) bore and 140-mm. (5.51-in.) stroke, shown at the left of Fig. 16. The high temperatures developed were due to the cooling blast being directed on the inlet side of cylinder.

With good valve-cooling it is possible to maintain a black rim on the valve-head under all conditions. With 1½-in. diameter valves the maximum temperature of any part of the valve should not exceed 1200 deg. fahr., and with valves up to 2½ in. in diameter it is possible to avoid temperatures in excess of 1350 deg. fahr., although this is at times accomplished at the expense of fuel economy. In general, for air-cooled engines I prefer to avoid the use of exhaust valves in excess of 2-in. diameter. Internal valve-stem cooling by water or mercury has been used with success. However, in my opinion, equally efficient results generally can be obtained with less expense and complication by greater care in the cooling design of the cylinder body. The amount of oil reaching the combustion-chamber has a considerable influence on the valve temperature, and an increase in the oil supply is often sufficient to reduce the exhaust-valve temperature to the point at which reliability is obtained.

There are several probable reasons why an air-cooled cylinder should have as good exhaust-valve cooling as a water-cooled cylinder. These are (*a*) the metal sections of the head and the valve ports have sufficient heat-flow capacity to carry heat to the cooler portions of the head; (*b*) the intensity of the heat-flow to the cooling medium is lower on account of the area of the attached fins; (*c*) with good design, the cooling medium surrounding the exhaust-ports and the adjacent portions of the head is in a violent state of turbulence, and semi-stagna-

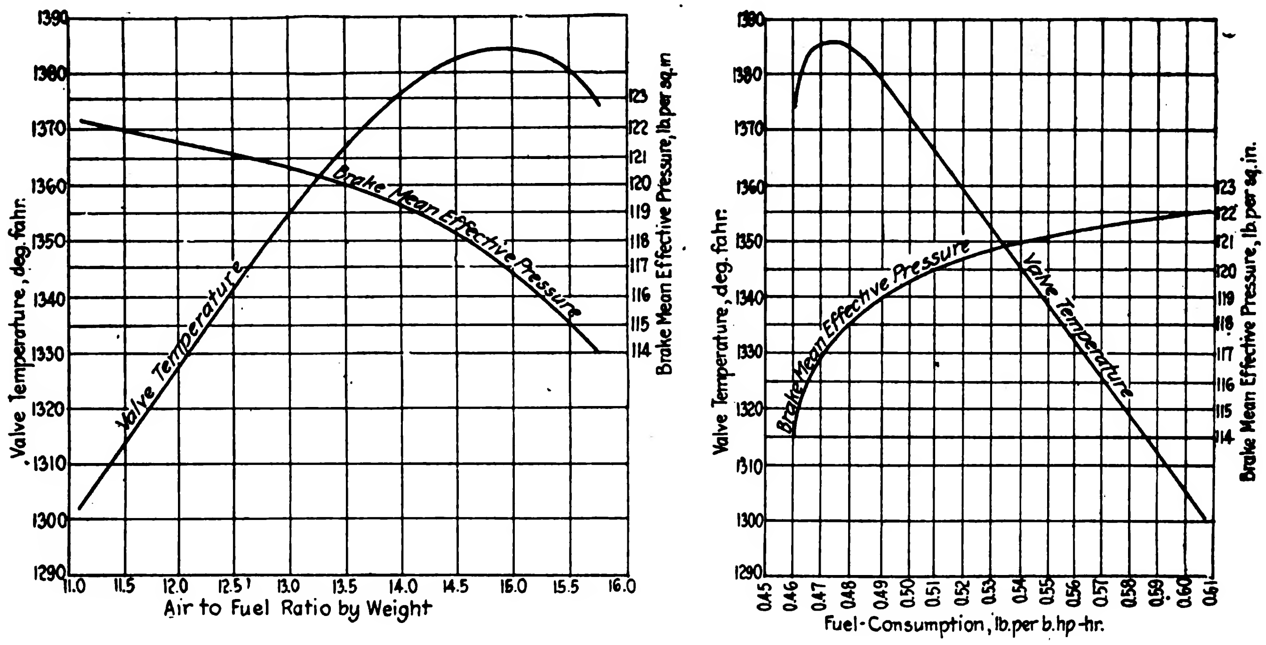


FIG. 26—CHARTS SHOWING THE VARIATION OF THE EXHAUST-VALVE TEMPERATURE AT THE LEFT WITH VARIOUS MIXTURE-STRENGTHS AND AT THE RIGHT WITH DIFFERENT SPECIFIC FUEL-CONSUMPTIONS

tion of the cooling medium, which may occur in a water-cooled engine, cannot well occur in an efficient air-cooled cylinder; (*d*) no equivalent of a steam-pocket can exist and local overheating does not result in practically complete failure of cooling at that point, such as occurs when a steam pocket develops in a water-cooled cylinder; (*e*) no equivalent of lime-salt deposits and resultant heat-insulation can occur; and (*f*) a parallel to an insulating film of steam does not exist. If a valve in an air-cooled cylinder runs cooler than a valve of equal size in a similar water-cooled cylinder, it is not unreasonable to assume that the exhaust port and the seat are cooler in the former. From observation it has been found that it is not possible to maintain a wetted surface with semi-stagnant water on metal at anything like the temperaures, 500 deg. fahr., developed around the exhaust-seat of an air-cooled cylinder. Water will remain almost quiescent and in apparently close contact with metal at 500 deg. fahr. for a considerable time with little evident evaporation or transfer of heat from the metal to the fluid; a 50-per cent reduction in the temperature of the metal, however, will produce violent evaporation.

Enclosing the valve-stems and the guides and lubricating them with oil improves exhaust-valve cooling. This alone is sufficient ground for a positively lubricated valve-gear, apart from other obvious advantages.

VALVE-GEARS

Most designs of spherical-head cylinder necessitate valve-gears of rather freakish appearance. Two such examples, involving odd compound motions, are seen in the B.S.A. and Type J cylinders. It can only be said that such freakish gears have better mechanical properties than appearance and really function with considerable reliability. The motion in three planes, existing at the push-rod ball-end where it works in the rocker-cup, does not produce much trouble in practice.

The use of an exposed push-rod valve-gear, in which lubrication is a matter of chance, is really crude in the extreme. Rocker-pivot lubrication can be made reasonably satisfactory by special bearings and greases. The rocker ball-ends can be enclosed in gaiters. Provision can be made to maintain a constant tappet clearance by heating the push-rods or by mechanical clearance compensation. However, when all these provisions are made, the result compares poorly with that of a fully enclosed valve-gear, in which the valve-stems, the springs, the rockers and the push-rods are entirely enclosed and run in oil. A fully enclosed valve-gear avoids most of the objectionable shock, wear, noise and excessive change of tappet clearance and valve-timing encountered in the average open push-rod valve-gear. The air-cooled engine cannot hope to compete with the high-class water-cooled engine, if it be equipped with a noisy and rapidly wearing valve-gear, requiring almost daily adjustment and lubrication.

CONCLUSIONS

There is a very general tendency to assume that air-cooling is suitable only for small cylinders. It may be well to quote the performance of the R.A.E. 19T cylinder, illustrated in Fig. 11, to show the extent to which the air-cooling of large cylinders has gone. This cylinder is of 8-in. bore and 10-in. stroke, or of 502.6-cu. in. capacity, and has developed 129 b. hp., or 119.5-lb. per sq. in. brake mean effective pressure at 1700 r.p.m., with a fuel-consumption of 0.51 lb. per b. hp-hr. The cylinder was built to determine the possible limits of air-cooling and, although in my opinion it has at present little practical application, it has at least demonstrated that successful air-cooling is not limited to 50 b. hp. per cylinder.

Fragility is a disadvantage of air-cooling as at present developed, the fins of a cast-iron automobile-engine cylinder of even the sturdiest design being relatively delicate in comparison with the cast-iron water-cooled block of an engine for similar use. There is little to choose, however, between the fragility of aircraft types if the composite aluminum and steel air-cooled cylinder be compared with the built-up all-steel water-cooled cylinder. In fact, the former, if anything, has the advantage, as detonation, preignition or vibration will often crack water-jackets but does not result in fin damage. It is not possible at present to produce air-cooled engines having the delightfully clean outline of such water-cooled engines as the Hispano-Suiza or Frontenac.

The design of air-cooled cylinders has suffered in the past much owing to compromise, this generally taking place at the expense of cooling efficiency, really the last feature that should be tampered with. To design an engine complete but for the cylinder, then design a cylinder to fit the engine body and finally endeavor to imagine how air can be supplied to the cylinders is a not unusual proceeding, and one that is not calculated to improve the faith of the general public in air-cooling.

APPENDIX 1.

Effect of Spark-Plug Position on Power Output and Fuel-Consumption

Air-cooled cylinders are markedly sensitive to spark-plug position. The location of the plug in the combustion-chamber relative to the inlet and exhaust-valves and the location of the plug points relative to the cylinder wall are both of considerable importance. Both phases of spark-plug location have been the subject of considerable research at the hands of Dr. A. H. Gibson[7] and Dr. E. G. Ritchie at the Royal Aircraft Establishment. The general result of their investigations has been to show that (*a*) the plug should not be located so that the flame-wave will be projected against a red-hot exhaust-valve and (*b*) the plug points should be approximately flush with the cylinder-wall. The best location of the plug points relative to the cylinder generally has to be determined for each design of cylinder; in some cases it is found that the best result is obtained with the points slightly pocketed; in other cases slightly projecting points prove best.

Some results obtained with double-plug ignition on the Airco four-valve cylinder, see Figs. 1 and 9, are shown in Figs. 27 and 28. The tests were made on two cylinders of differing performance due to valve-seat insert material and contact and the two charts reproduced in Fig. 27 show the relation between the brake mean effective pressure and the fuel-consumption for the two cylinders respectively with various combinations of plug position. The plug points were approximately flush with the cylinder-wall in all the tests. The two cylinders had one combination of plug position common to both, that of the two horizontal side plugs shown in the upper left corner of Fig. 28, and this has been used to reduce to a common basis the performance of both cylinders with various plug positions. The performance on maximum-load mixture of both cylinders with this plug position has been taken as a datum. For each cylinder the several fuel-consumptions and the brake mean effective pressures have been plotted as percentages of the corresponding values on maximum-load mixture with the common plug position. It will be noted from Fig. 28 that the values obtained with this plug position on both cylinders lie fairly close to the mean curve, which apparently justifies this method of reducing performance to a common basis. The method of reduction is open to objection but it is difficult to find any other that can be used.

From Fig. 28 it appears that the use of two horizontal head plugs is decidedly the best. From this it seems that the plugs should lie on a common horizontal axis passing through the vertical axis of the combustion-chamber, and that the location of the plug axis should be such that neither plug can project a flame-wave against the exhaust-valves. Drs. Gibson and Ritchie found that the plug should be located so that the points will be swept alternately by the ingoing charge and the outgoing exhaust, thus both cooling the points and burning-off the oil or the carbon.

The unsatisfactory performance given with two inclined head plugs was confirmed by tests on other cylinders of the same design, as well as by those used in the tests mentioned. Although quantitative figures were not obtained, it was found that switching from the two horizontal side plugs to the two inclined head plugs at once caused an increased detonation and a drop in the power output, this occurring over a wide range of mixture-strength.

By obtaining comparisons of the effect of plug position from curves with the brake mean effective pressures plotted against the fuel-consumptions from the maximum-load to the weakest possible mixture, although the latter was not determined for all plug positions, errors due to a single observation are in the main avoided, and the effect of any plug location is examined over a wide range of mixture-ratios. It is not contended that the results of these tests apply to other than this particular design of cylinder. Other designs, nevertheless, have in general confirmed the results reproduced in Fig. 28.

APPENDIX 2

Influence of Gas Velocity Through the Valves on the Performance of an Air-Cooled Engine

The investigation described herein was undertaken to secure data on the effect of gas velocity on performance, in particular on that of air-cooled aircraft engine cylinders. The tests were carried out on Airco aircraft-engine cylinders (see Figs. 1 and 9) fitted up on an R.A.E. single-cylinder universal test engine.

Owing to cooling difficulties, valve sizes such as are used on automobile engines are impossible on the high

[7] See *Transactions of the Royal Aeronautical Society*, No. 3.

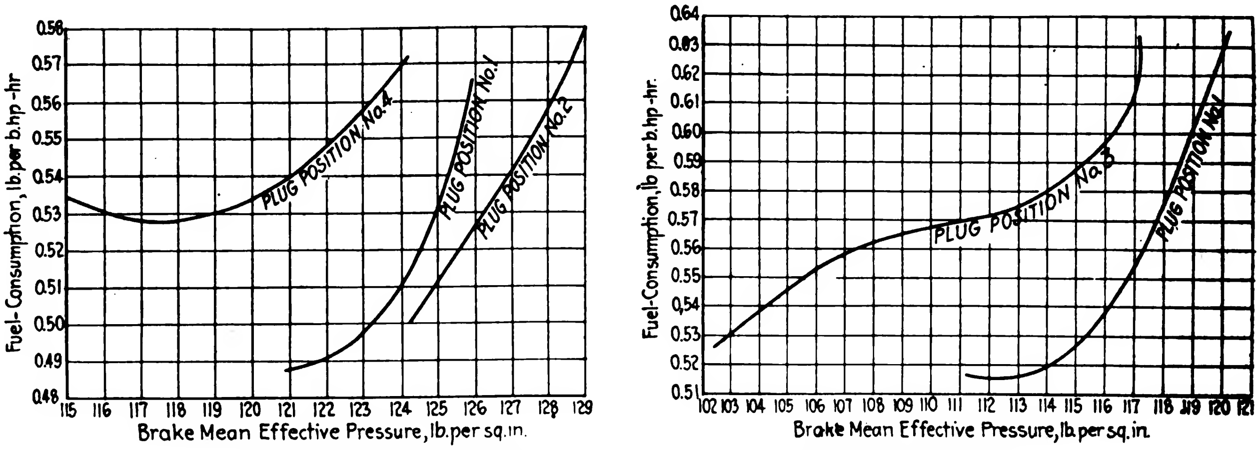


Fig. 27—Results of Spark-Plug Location Tests on the Airco Cylinder

efficiency air-cooled cylinder. In the three and four-valve types of cylinder, such valving as is used by some American water-cooled aircraft-engine constructors leads to serious cooling difficulties, the principal source being the bridge between the exhaust-valves. The development in Europe of the air-cooled cylinder of high output has resulted in the adoption of relatively small valves used in conjunction with high lifts. Attempts to valve air-cooled aircraft-engine cylinders, particularly of the three and four-valve types, on the proportions used for air-cooled racing motorcycle engines have resulted in failure; it is by no means uncommon to find the latter type of cylinder in the 30-cu. in. size fitted with four overhead valves of approximately 1½-in. diameter in the port. Such design is possible only with small cylinders and with en-

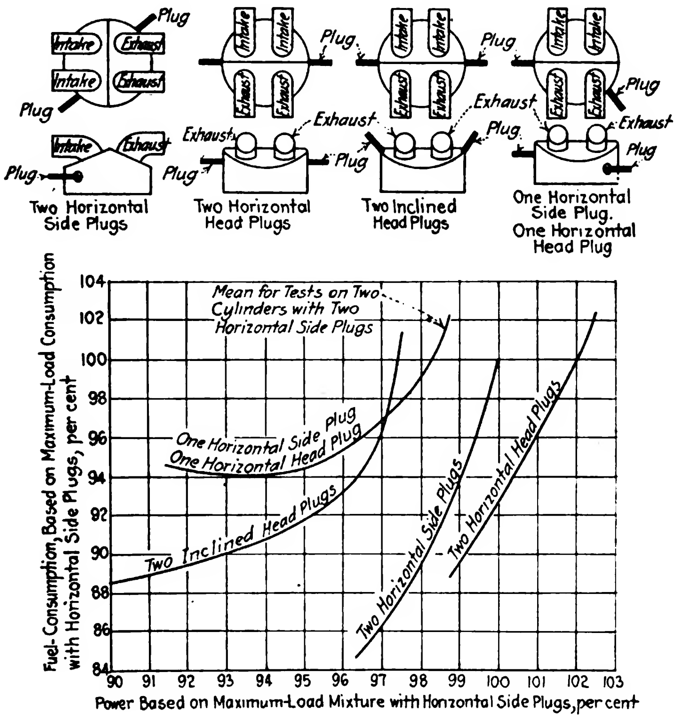


FIG. 28—EFFECT OF SPARK-PLUG POSITION ON THE POWER AND FUEL-CONSUMPTION OF THE AIRCO CYLINDER

gines that do not run on full throttle for long periods. Experience tends to show that even for intermittent short bursts at full throttle, the engine having high gas velocities and good valve-cooling will give better power and performance than the type having a combustion-chamber consisting mainly of valves, and that, in spite of the marked advantages of overhead valves for air-cooled engines, their advantage is mainly lost if overvalving is attempted. In small cylinders the first-class L-head type will usually prove greatly superior to the overvalved overhead-valve type if any protracted full-throttle running is attempted.

Investigation to date indicates that for aircraft-engine cylinders the two-valve type is best for capacities of up to 100 cu. in. and that beyond this size the four-valve type is superior; although two-valve cylinders of up to 160-cu. in. capacity have been built and given excellent results. The large two-valve type, however, is not as a rule suitable for speeds in excess of 1700 r.p.m., usually involving very high gas-velocities through the valves and not giving nearly such a high performance as the best class of four-valve cylinders. Experience has shown that unless a four-valve air-cooled cylinder of up to 160-cu. in. capacity is very carefully designed, the perform-

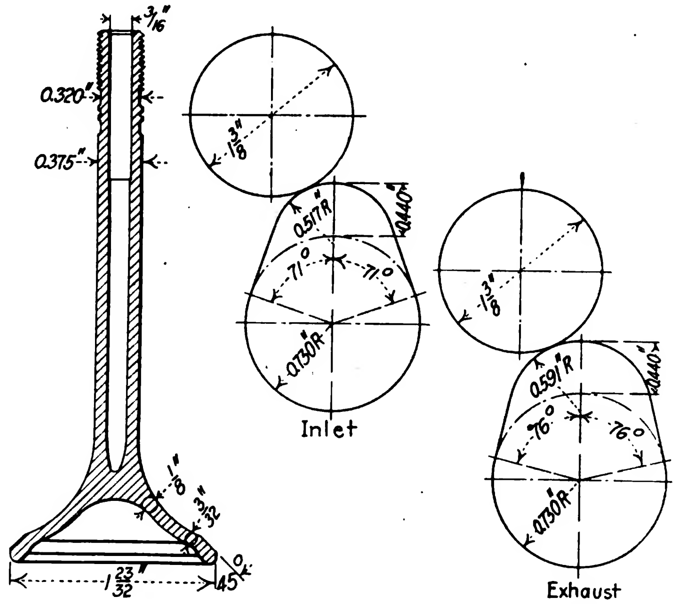


FIG. 29—AT THE LEFT THE VALVE USED IN THE AIRCO CYLINDER AND AT THE RIGHT THE INLET AND EXHAUST-VALVE CAMS

ance will be inferior to that of a good two-valve design of similar size. Large three and four-valve cylinders of the flat-head type have proved to be much less efficient than the two-valve spherical-head type.

Several methods are in use as a basis for calculating gas velocities. One merely considers the mean velocity in the port, on a basis of filling or exhausting the cylinder during 180 deg. of crankshaft rotation. This method is crude, as no account is taken of valve-lift, this latter factor having a considerable influence on the power output.

A second method considers the mean velocity through a cylindrical annulus of a diameter equal to the bore of the mouth of the port and a height equal to the maximum

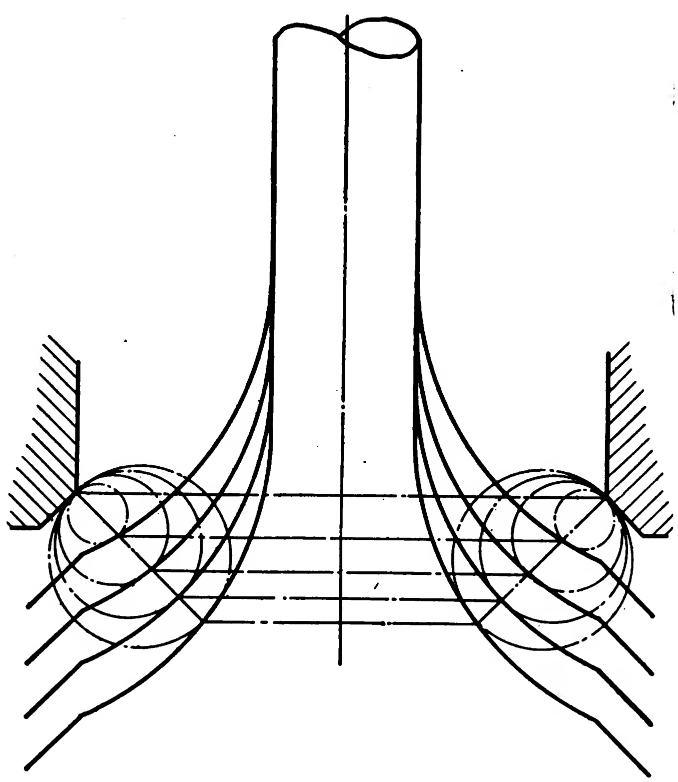


FIG. 30—DIAGRAM SHOWING METHOD OF OBTAINING ANNULI AREAS GRAPHICALLY

valve-lift, this annulus being taken as constant throughout the period of filling or exhausting. The time of filling or exhausting is taken as 180 deg. of the crankshaft rotation, the cylinder is assumed to be completely filled and the charge is assumed to be at normal temperature and pressure. This method takes no account of the mean valve-lift or of timing, both of which factors have a considerable influence on the performance. Cylinders having very small valves will usually show an improvement in the power output when an increase of the mean valve-lift is made without any change of the maximum lift. The same holds true as regards timing, very small valves with high gas-velocities generally requiring freak timing with long opening-periods to give the maximum performance.

A third method considers the mean of the true areas in the annulus normal to the seat, the true time of opening and 100-per cent volumetric efficiency. In my opinion this method is the soundest, but is too cumbersome for general use as it involves a graphical layout to determine the areas of the conical annuli from zero to the maximum lift. With this method annuli areas in excess of the net area in the throat, or the port area less the valve-stem area, are neglected. One result of studying this method has been to show some cause for the advantages in performance gained by the use of high-lift valves. It has been commonly supposed that high lifts involved overlifting, and that the gain was due to the increase of the average lift rather than from any useful effect of the maximum lift itself. However, graphical investigation of annuli areas has shown that with the small valve-diameters and high lifts employed, little overlifting occurred. As a result the general formula for the conical annulus area given in most textbooks was examined and found to be incorrect. This formula assumes that the diameter of the base of the cone increases with increasing lift; this, however, does not hold good with tulip valves where the tulip neck has a barely perceptible junction with the seat. The left portion of Fig. 29 shows a valve used as a 1½-in. exhaust and inlet and a 1 9/16-in. inlet. In the latter case the base of the cone has a constant diameter equal to that of the port. As the tulip type certainly does not pass less gas than the flat-head type, it appears that the theoretical increase of area with the flat-head type of valve is of no practical moment, and that the gas does not depart from streamline-flow conditions and abruptly change its course around sharp corners to take advantage of sudden increases of area. The graphical method of obtaining annuli areas is shown in Fig. 30. The conical annulus as a basis for the calculation of area is cumbersome, as its relation to the cylindrical annulus of equal height diminishes progressively with the lift. I consider that a reasonable and not altogether cumbersome basis for the estimation of velocity is that of the cylindrical annulus. This is supported to a certain extent by the fact that a 45-deg. seat valve, with less area in the annulus than either a flat seat or a 30-deg. seat valve will, in overhead-valve cylinders, pass at least as much gas as either of the latter types at equal lift, showing that the reduction of area is balanced by the more nearly streamline-flow conditions.

It is my view that the all-around best valve-seat angle for overhead-valve cylinders is 45 deg. The seat angle is considered to be most important in multiple-valve cylinders with pairs of valves in close proximity. The converging gas-streams with pairs of similar valves will meet less nearly head-on with 45-deg. seats than with flat or 30-deg. seats.

The gas velocities for the cylinders used in the tests were worked out by three methods; (*a*) on the basis of a cylindrical annulus, the mean valve-lift and the time of opening; (*b*) on the basis of a true mean area of the annulus and the time of opening; and (*c*) on the basis of a cylindrical annulus with the valve held at full lift for 180 deg. of the crankshaft rotation.

The particulars of the cylinders tested and the valve-timing are as follows:

Bore of Cylinder, in.	5½
Stroke, in.	6
Volume of Cylinder, cu. in.	142.6
Inlet-Valve Opens	10 deg. early
Inlet-Valve Closes	45 deg. late
Period of Inlet-Valve	235 deg.
Exhaust-Valve Opens	55 deg. early
Exhaust-Valve Closes	15 deg. late
Period of Exhaust-Valve	250 deg.
Basic Speed, r.p.m.	1,800
Time Inlet-Valve Is Open, sec.	0.0218
Time Exhaust-Valve Is Open, sec.	0.0232

Case 1

Two 1 9/16-In. Inlet-Valves

Maximum Lift, in.	0.590
Mean Lift, in. (see Fig. 31)	0.361

Area of Both Annuli $= 2 \times 1.5625 \times 3.14 \times 0.361 = 3.54$ sq. in.

Velocity in feet per second equals the cylinder capacity in cubic inches divided by 12 times the product of the time of opening in seconds and the area of the valve-opening in square inches. Substituting numerical values, we have

$V = (142.6) \div (12 \times 0.0218 \times 3.54) = 154$ ft. per sec.

Case 2

Two 1 9/16-In. Inlet-Valves

Maximum Lift, in.	0.590
Mean Annulus Area, sq. in. (see Fig. 31)	2.420

$V = (142.6) \div (12 \times 0.0218 \times 2.42) = 225$ ft. per sec.

Case 3

Two 1 9/16-In. Inlet-Valves

Maximum Lift, in.	0.590

Opening Area $= 2 \times 1.5625 \times 3.14 \times 0.59 = 5.79$ sq. in.

Time of Opening at 1800 r.p.m. $= \frac{1}{2}$ revolution $= \frac{1}{2} \times 1/30 = 1/60$ sec.

$V = (142.6 \times 60) \div (12 \times 1 \times 5.79) = 123$ ft. per sec.

It is concluded that the first basis of cylindrical annulus, mean lift and true time of opening is the most useful method and the figures given in Table 10 are thus obtained, while the figures derived from the other two methods used are included for the purpose of comparison.

The tests were all carried out with constant conditions of blast speed, compression-ratio, valve-timing, character of fuel, oil temperature, and oil supply. The same inlet and exhaust-cams were used throughout. Unfortunately, the rockers used when only one valve of a similar pair was in operation had a different multiplication than that used when both valves were working.

The Claudel carbureter employed was fitted with a variable jet by which the fuel supply was adjusted in each test to give the weakest mixture that would develop the maximum power. The fuel-consumption figures are the least satisfactory portion of a somewhat ragged investigation, as on a single-cylinder engine fitted with a very heavy flywheel it is a matter of some difficulty to spot the exact maximum-load mixture. Further, the use of one large carbureter for both inlet-valves is not altogether satisfactory when one valve is cut out. A carbureter for each inlet port would doubtless be much more suitable.

The tests were carried out on two cylinders which had slightly differing performances. The cylinder with the 1 9/16-in. inlet and the 1½-in. exhaust-valves had an inferior performance at speeds above and below 1700 r.p.m.,

TABLE 10—GAS-VELOCITY TEST RESULTS

Inlet-Valves Number	Inlet-Valves Diameter, in.	Inlet-Valves Hot Lift, in.	Exhaust-Valves Number	Exhaust-Valves Diameter, in.	Exhaust-Valves Hot Lift, in.	Speed, r.p.m.	Power, b.hp.	Brake Mean Effective Pressure, lb. per sq. in.	Fuel-Consumption, lb. per b. hp-hr.	Temperature, deg. fahr. TH_3	Temperature, deg. fahr. Tp	Mean Gas-Velocity through Inlet-Valve Annulus, ft. per sec. Case 1	Case 2	Case 3	Mean Gas-Velocity through Exhaust-Valve Annulus, ft. per sec. Case 1	Case 2	Case 3
2	$1\frac{9}{16}$	0.59	2	$1\frac{1}{2}$	0.59	1,600	34.6	120.0	0.59	427	.....	137	....	....	134	....	....
						1,700	39.2	128.0	0.60	427	.....	145	....	....	143	....	....
						1,800	40.2	124.0	0.58	432	.....	154	225	123	151	217	128
						1,900	41.1	120.0	0.52	467	.....	163	....	....	159	....	....
2	$1\frac{9}{16}$	0.59	2	$1\frac{3}{8}$	0.59	1,200	25.4	117.5	0.61	389	390	103	....	....	110	....	....
						1,400	31.0	123.0	0.60	407	414	120	....	....	128	....	....
						1,600	36.9	128.0	0.57	450	468	137	....	....	146	....	....
						1,700	39.5	129.0	0.56	452	473	145	....	....	156	....	....
						1,800	40.9	126.0	0.56	462	473	154	225	123	164	255	140
						1,900	42.1	123.0	0.56	463	477	163	....	....	174	....	....
						2,000	43.1	119.5	0.56	515	522	171	....	....	183[i]	....	..
1	$1\frac{9}{16}$	0.53	1	$1\frac{3}{8}$	0.53	1,400	28.0	111.0	0.56	360	522	266	....	....	288	....	....
						1,600	28.2	98.0	0.56	378	550	304	....	....	328	....	....
						1,700	28.0	91.5	0.56	378	558	323	....	....	349[j]	....	....
						1,800	27.9	86.0	0.56	388	576	342	486	274	369	532	312
						1,900	27.9	81.5	0.56	396	585	361	....	....	390	....	....
1	$1\frac{3}{8}$	0.53	1	$1\frac{9}{16}$	0.53	1,400	25.2	100.0	0.60	333		290	....	....	253	....	....
						1,600	25.8	89.5	0.54	351		332	....	....	289	....	....
						1,700	25.7	84.0	0.54	355	k	352	....	....	307	....	....
						1,800	25.6	79.0	0.58	300		373	573	312	324	449	274
						1,900	25.2	73.5	0.61	370		394	....	....	343	....	....
2	$1\frac{9}{16}$	0.59	1	$1\frac{3}{8}$	0.53	1,400	30.5	121.0	0.59	378	522	120	....	....	288	....	....
						1,600	33.6	116.5	0.59	414	593	137	....	....	329[l]	....	....
						1,700	33.4	109.0	0.59	432	638	145	212	116	349	502	295
1	$1\frac{9}{16}$	0.53	2	$1\frac{1}{2}$	0.59	1,400	27.5	109.0	0.61	423	.....	266	....	....	117	....	....
						1,600	29.7	103.0	0.61	423	.....	304	....	....	134	....	....
						1,700	30.0	98.0	0.59	423	.....	323	....	....	143	....	....
						1,800	30.0	92.5	0.56	450	.....	342	486	274	151	217	128
						1,900	29.4	86.0	0.52	450	.....	361	....	....	159	....	....
1	$1\frac{9}{16}$	0.53	2	$1\frac{3}{8}$	0.59	1,800	30.2	93.0	0.52	459	.....	342	486	274	164	255	140
						1,900	30.3	88.5	0.52	450	.....	361	....	....	174	....	....

[i] Exhaust port was overheating somewhat at 2000 r.p.m.
[j] Exhaust port overheating; exhaust-valve area and port capacity obviously insufficient.
[k] No port temperatures taken. No signs of exhaust-port overheating.
[l] Violent overheating of exhaust-valve and port at 1600 and 1700 r.p.m. At the latter speed the whole of the exhaust-valve seat, the neck and that portion of the stem not shrouded by the guide were at a red heat of between 1400 and 1500 deg. fahr. With all four valves in operation, only the necks of the exhaust-valves became red, the temperature of the red zone varying between 1000 and 1150 deg. fahr., according to the speed and the mixture-strength.

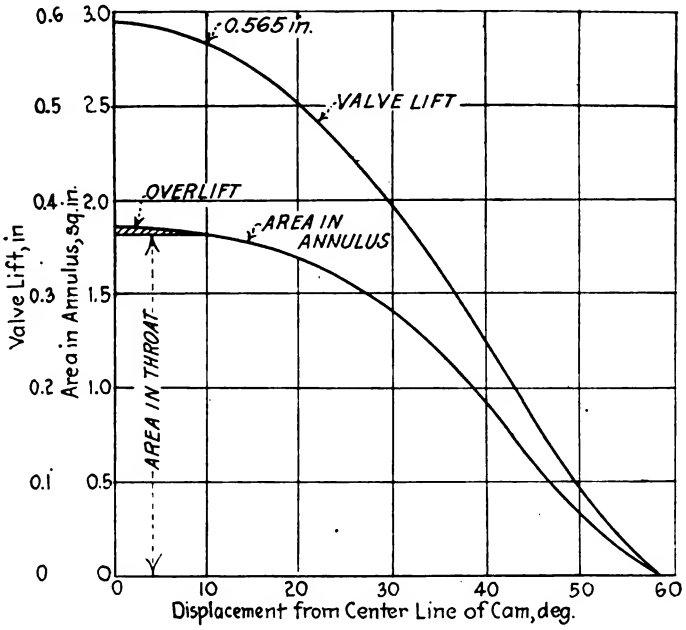


FIG. 31—INLET-VALVE LIFT DIAGRAM FOR A 1 9/16-IN. VALVE
The Maximum Lift of the Valve was 0.590 In., and the Mean Lift Was 61.1 Per Cent of the Maximum or 0.361 In. The Mean Area Through the Annulus was 1.21 Sq. In. and the Net Area in the Throat Was 1.81 Sq. In.

this being due to the fact that the cast-in valve-seat inserts were loose when the cylinder was hot, which caused leakage at the lower speeds and hotter exhaust-valves, due to the reduced heat-flow from the seatings to the cylinder-head, at the higher speeds. With all four valves in operation, this design of cylinder always developed its maximum brake mean effective pressure at 1700 r.p.m., irrespective of mechanical defects, fuel, timing and the compression-ratio used; and it is noticeable that the performance at this speed differs only slightly between the two cylinders. The figures given in the table represent the average of a number of tests.

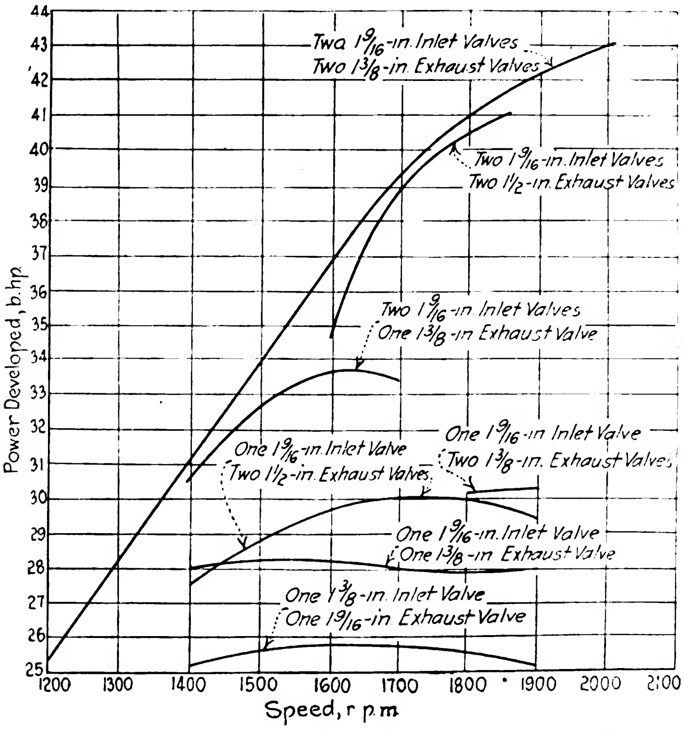


FIG. 32—RESULTS OF TESTS MADE WITH VARIOUS SIZES AND COMBINATIONS OF INLET AND EXHAUST-VALVES
The Results of These Tests Are Presented in Table 10

The fuel employed was a mixture of 80 per cent by volume of American aviation gasoline with 20 per cent of benzol having a specific gravity of 0.88, the specific gravity of the mixture being 0.74. Castor oil was employed for lubrication. The Claudel carbureter was equipped with a 44-mm. (1.73-in.) choke and a Type Z diffuser. The compression-ratio was 5.1 to 1 and the blast, which had a velocity of 87 m.p.h., was applied on the exhaust-side of the cylinder.

The valve diameters in every case are the clear diameters in the ports. The power readings are all maintained values and not snatch readings. Both the brake-horsepower and the brake-mean-effective-pressure readings are corrected to a barometric pressure of 29.9 in. of mercury and an air temperature of 59 deg. fahr. The cylinder-head temperatures were taken at TH_1, the hottest point on the head, and the exhaust-port temperatures were taken at the point T_p, the location of these points being shown in Fig. 1. All temperature readings are in fahrenheit degrees and are the values above the air temperature.

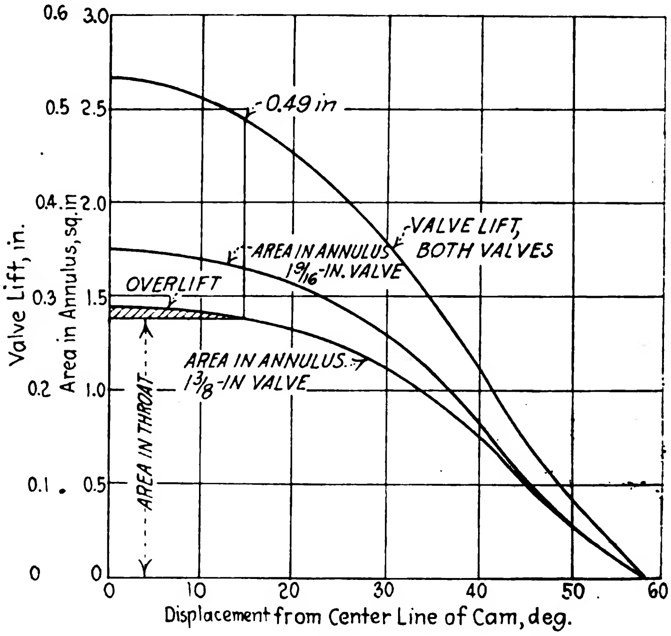


FIG. 33—INLET-VALVE LIFT DIAGRAM FOR A 1 9/16 AND A 1 3/8-IN. VALVE
The Maximum Lift of Both Valves Was 0.530 In. and the Mean Lift was 61.1 Per Cent of the Maximum or 0.324 In. The Mean Area Through the Annulus for the 1 9/16-In. Valve was 1.12 Sq. In. and 0.95 Sq. In. for the 1 3/8-In. Valve. The Net Areas in the Throat for the Two Valves Were 1.81 and 1.87 Sq. In. Respectively

For an air-cooled engine the results appear to indicate that

(1) The exhaust and the inlet-valves should be of approximately equal diameter and have equal lifts
(2) A mean gas-velocity through the valve annulus of from 140 to 160 ft. per sec., as calculated on the first of the three previously mentioned bases, seems

TABLE 11—TESTS OF AN AIRCO CYLINDER

Speed, r.p.m.	1,700	1,900
Power Developed, b. hp.	42.2	46.5
Brake Mean Effective Pressure, lb. per sq. in.	138	136
Fuel-Consumption, lb. per b. hp-hr.	0.56	0.56

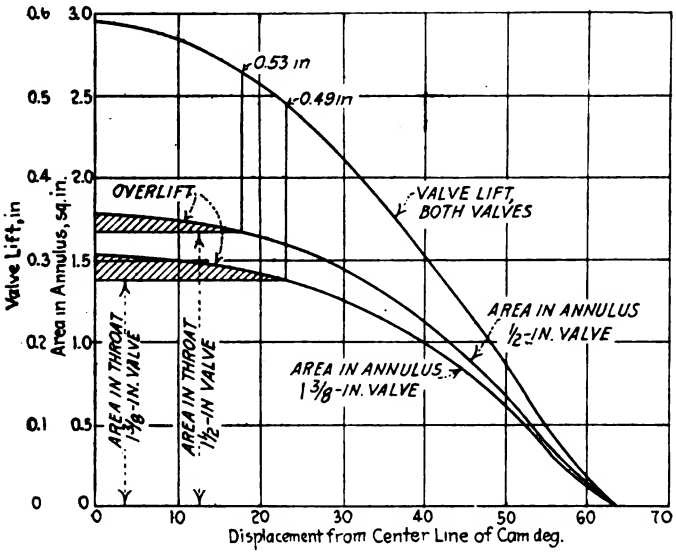


FIG. 34—EXHAUST-VALVE LIFT DIAGRAM FOR A 1½ AND A 1⅜-IN. VALVE

The Maximum Lift Was 0.590 In. and the Mean Lift was 61.5 Per Cent of the Maximum or 0.363 In. The Mean Area Through the Annulus for the 1½-In. Valve Was 1.19 Sq. In. and 1.01 Sq. In. for the 1⅜-In. Valve. The Net Areas in the Throat Were 1.66 and 1.37 Sq. In. Respectively

to give the maximum performance with valves of between 1⅜ and 1⅝ in. diameter.

The first conclusion has exceptions, as in large two-valve cylinders the exhaust-valve is often made smaller than the inlet for valve-cooling reasons with satisfactory results. Such an arrangement usually requires an excessive exhaust-opening period to produce the best results, in spite of running generally at a somewhat lower speed than the four-valve type.

Experience tends to show that with an increase of the valve size the velocity through the annulus can be increased considerably without affecting the brake mean effective pressure. This is probably due to the decrease in friction in the port, owing to the increase of the ratio between the port-area and the maximum area in the annulus, as is brought out in some later remarks on the Type J cylinder. A large two-valve cylinder, having gas velocities approximating those of the four-valve type used in the tests, is very difficult to produce successfully. Large valves, if crowded into the combustion-chamber, will result in cooling troubles, and a decrease of the gas velocity by an increase of the lift beyond ⅝ in. generally results in severe mechanical difficulties.

The conclusions arrived at are all obtained from single-cylinder tests in which large carbureters were used, with the result that the point of maximum torque was not materially affected by manifold-depression. Assumptions as to the most efficient gas-velocity from multi-cylinder engine performance may prove misleading on account of the large variations in the manifold-depression on different engines.

It is not contended that the results are by any means quantitative or more than a general guide. However, it is considered that the possibilities of the relatively small valve with high lift are indicated. That small valves are no barrier to high brake mean effective pressures is shown by the performance obtained with the Airco cylinder at a later stage of development, when the results given in Table 11 were obtained. This cylinder had two 1½-in. exhaust and two 1 9/16-in. inlet-valves. The compression-ratio was 5.3 to 1. No case of burnt valves occurred in several hundred hours testing on this type of cylinder. The only valve trouble experienced was the shearing of the rim of the exhaust-valve due to loose valve-seat inserts, and even in this case the trouble did not develop until after well over 100 hr. of full-throttle running per valve.

The type of tulip valve used in the tests is shown at the left of Fig. 29, the material for the valves being 13-per cent chromium steel. This drawing shows the general proportions of the valves used in air-cooled cylinder development at the Royal Aircraft Establishment, these being similar to those used in some of the best British water-cooled engines. I have used the results of these tests as a basis of valving for the design of new cylinders with a fair degree of success.

The brake-horsepower results shown in Table 10 are plotted against the speed in Fig. 32. The lift diagrams for all the sizes of valve used with various maximum lifts and timing are reproduced in Figs. 31, 33, 34 and 35. The inlet and exhaust cams used for all tests are illustrated at the right of Fig. 29.

Since the tests described were written up, others have been carried out on the Type J cylinder shown in Fig. 7 by the engineering division and are of interest as they tend to confirm the possibilities of relatively small valves with high lifts for air-cooled cylinders. The cylinder, which was of 5⅝-in. bore and 6½-in. stroke and had a capacity of 161.5 cu. in., was fitted with one 2½-in. inlet-valve and one 2¼-in. diameter exhaust-valve, both having a hot lift of 0.59-in. The compression-ratio was 5.3 to 1 and the blast velocity 90 m.p.h. The fuel was an 80-20-per cent gasoline-benzol mixture.

It is of interest to note that this cylinder is of 18-per cent greater capacity than the Liberty engine cylinder and has a similar size of inlet-valve and an exhaust-valve of ¼-in. less port diameter. In spite of the fact that the exhaust-valve is smaller and yet passing considerably more gas, and that the cylinder is air-cooled, the exhaust-valve cooling is at least as good as that of the Liberty engine, when running on a single-cylinder engine

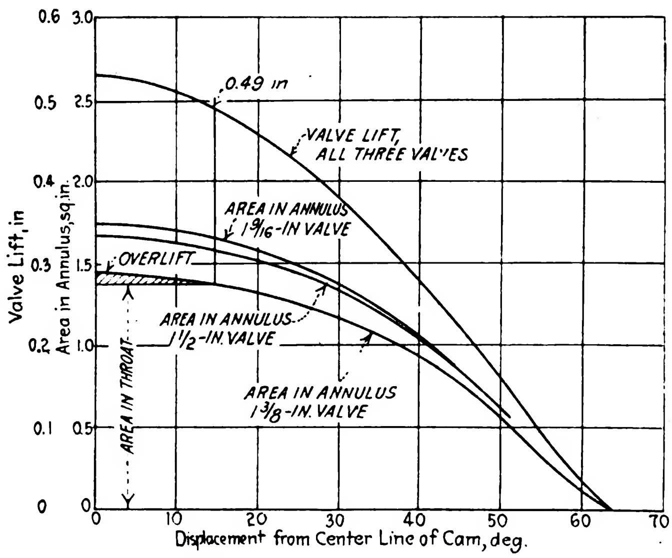


FIG. 35—EXHAUST-VALVE LIFT DIAGRAM FOR 1 9/16, 1½ AND 1⅜-IN. VALVES

The Maximum Lift Was 0.530 In. and the Mean Lift Was 61.5 Per Cent of the Maximum or 0.326 In. in All Cases

Size of Valve, In.	1⅜	1½	1 9/16
Mean Area through Annulus, sq. in.	0.97	1.11	1.15
Net Area in Throat, sq. in.	1.37	1.66	1.81

at a similar brake mean effective pressure, compression-ratio and fuel-consumption.

It will be noted that from Table 12 the gas velocities are very high and the performance by no means poor for a cylinder of this size, whether water or air-cooled. The timing used is of an extreme character, the inlet-valve opening 23 deg. early and closing 59 deg. late while the exhaust-valve opens 75 deg. early and closes 20 deg. late, and is not of the type likely to give very good idling, but was found by experiment on a similar design of cylinder to give the best all-around performance at full power.

TABLE 12—TEST OF A TYPE J CYLINDER

Speed, r.p.m.	1,450	1,550	1,650[m]	1,750	1,850
Power Developed, b. hp.	38.1	41.2	44.1	46.8	48.7
Brake Mean Effective Pressure, lb. per sq. in.	128.8	130.2	131.1	131.1	129.1
Fuel-Consumption, approximate, lb. per b. hp-hr.	0.56	0.56	0.56	0.56	0.56
Gas Velocity through Intake,[n] ft. per sec.	149	159	169	179	189
Gas Velocity through Exhaust,[n] ft. per sec.	157	167	178	189	200

[m] Normal speed.
[n] Calculated on the basis of Case 1.

The power and the brake mean effective pressure results are corrected only for the barometer. The mechanical efficiency of the single-cylinder test engine was about 84 per cent in this test and the results have not been corrected up to a more normal mechanical efficiency. It will be noted from Table 12 that the gas velocities within the speed range shown are somewhat below that at which a marked reduction in the brake mean effective pressure became apparent on the Airco cylinder. This velocity by interpolation was approximately 220 ft. per sec.

LETTER BALLOT ON ADOPTION OF STANDARDS

THE March 1922 issue of data sheets for the S.A.E. HANDBOOK was sent to the members last month. These data sheets contained, with the exception of the recommendation for Engine Numbers, the standards and recommended practices revised in accordance with the recommendations of the Standards Committee printed on page 383 of the December 1921 issue of THE JOURNAL and on page 121 of the February 1922 issue of THE JOURNAL and adopted by letter ballot of the voting members of the Society on March 11.

The Council authorized the withholding of the recommendation on Engine Numbers from publication in the S.A.E. HANDBOOK, owing to the fact that the proposed method of numbering engines so as to facilitate identifying stolen automobiles had failed of its purpose, numbers stamped in accordance with the proposed method being too susceptible to alteration by comparatively simple means.

Among the criticisms submitted in the letter ballots were some from members who had not thitherto indicated that they were opposed to the recommendations, although they had been published in THE JOURNAL before. Many of the objections had been given adequate consideration previously by the Divisions when formulating the respective recommendations.

Recommendations of Divisions are not voted upon for final adoption by the Members until they have been published at least once and generally twice in THE JOURNAL. Furthermore, information is published under the heading, Current Standardization Work, each month in THE JOURNAL as to the work in progress. This should enable members to keep in close touch with the work of the Standards Committee. Objections to any of the recommendations should be submitted by letter to the Society soon after the issuance of THE JOURNAL containing the respective Division reports, making it possible for objections to be considered by the proper Divisions or brought up for discussion at the Standards Committee Meeting.

Letters containing such criticisms are referred to the Standards Department, which carries on the secretarial work for the Standards Committee, and are edited and stenciled, enough copies being made for all the members of the Division or Divisions interested. If it is possible to handle the criticism by correspondence, comments are requested from Division members and these, when received, are distributed among all the Division members with the request that they review them and indicate what action they believe should be taken. A letter ballot is generally enclosed to facilitate this proceeding. If the matter cannot be handled by correspondence, a Subdivision is appointed to review the criticism or it is scheduled for discussion at the first Division meeting. Objections raised by Society members are, of course, given very careful consideration.

The complete vote on the recommendations is tabulated below. The first column gives the number of affirmative votes; the second column, the negative votes; and the third, the number of members who did not vote either way.

Subject	Yes	No	Not Voting
Tachometer Drive	107	0	225
Annular Ball Bearings	198	0	134
Roller-Chain Sprocket-Cutters	122	0	210
Roller Chains	125	1	206
Insulated Cable	155	1	176
Starting-Motor Flange Mountings	183	2	147
Flexible Steel Conduit	160	1	171
Non-Metallic Conduit	156	0	176
Carbureter Flanges	169	1	162
Engine Numbers	165	9	158
Fan-Belts and Pulleys	165	3	164
Mufflers	159	5	168
Running-Board Brackets	144	3	185
Iron and Steel Specifications	140	1	191
Bases, Sockets and Connectors	159	0	173
Lamp Glasses	163	0	169
Tail-Lamps	163	1	168
Non-Ferrous Metal Specifications	170	0	162
Rod-Ends	189	0	143
Taper Fittings	183	1	148
Water-Pipe Flanges	177	0	155
Lock-Washers	197	2	133
Passenger-Car Door-Handles	116	0	216
Passenger-Car Doors	119	0	213
Rubber Bushings	124	0	208
Wiring for Beads	121	1	210
Body Nomenclature	137	2	193
Pressure-Gage Connections	177	0	155
Tractor Drawbar Height	99	3	230
Transmission Tire-Pump Mounting	177	0	155
Clutch Facings	176	1	155
Three-Joint Propeller-Shafts	127	2	203

CHARGE FOR TRANSACTIONS DEFERRED

ACTION TAKEN BY COUNCIL AT ITS MARCH MEETING

DISTRIBUTION RESTRICTED TO MEMBERS ORDERING COPIES

ATTENTION was called in the February issue of THE JOURNAL to the action contemplated with regard to eliminating unjustifiable expense in connection with the printing and distribution of certain publications of the Society. At its meeting held in March, the Council, in view of sentiment expressed by some of the members, decided, under authority granted by the Constitution, to restrict the issuance of the TRANSACTIONS for the last half of 1920 and for the years 1921 and 1922 to members ordering them.

It was considered that this action will meet any implied obligations as a result of statements in membership literature of the Society. The Council, nevertheless, feels that inasmuch as the TRANSACTIONS are a duplication of matter published in THE JOURNAL, the free distribution of both permanently would be unjustifiable, and therefore beginning with Part I of Vol. 18 (1923) a nominal charge of $2 per part of TRANSACTIONS, to cover the expense of publication, will be made to those members who still desire them. The charge to non-members, except in the case of certain public and engineering libraries and Government bureaus, is $10.

Part II of Vol. 15 (1920), the two Parts of Vol. 16 (1921) and the two Parts of Vol. 17 (1922) will be sent without charge in addition to respective dues to members requesting them within 60 days of notice to order, which will be given in due course in all cases. A notice of the time to order Part II of 1920 TRANSACTIONS was mailed the members last month. A request form is also printed on the following page hereof.

There has been no increase in the amount of specified annual dues, commensurate in any way with the increased expense, during the growth of the Society in the past 16 years from a body of 100 or 200 to a world-wide organization of approximately 5500 members. Meantime the publications and the service afforded the members have increased greatly in kind and quantity. Originally practically the only publication furnished the members was the old-style TRANSACTIONS. Then the S. A. E. HANDBOOK was inaugurated, this being a semi-annual publication carrying no extra charge, for which, so far as is known, there is no parallel among engineering societies. In addition the *Bulletin* was instituted, this having been superseded several years ago by THE JOURNAL. Sections of the Society have been organized in increasing number. Recently the Research Department, which obviously will be of much value to the members, was established. For many years the Standards Department has been maintained and enlarged steadily in scope.

The cost per member for the work of the Society now exceeds $30 a year, excluding the cost of advertising and miscellaneous sales and membership-increase activity. The annual dues average less than $15 per member. The furnishing of the next five Parts of the TRANSACTIONS to the members without extra charge probably means that the reserve funds of the Society will have to be drawn upon to a considerable extent.

Special Notice

TRANSACTIONS, PART II OF VOL. 15 (1920).

To Those Who Paid Dues for the Second Half of the Fiscal Year Beginning Oct. 1, 1919:

The Council has directed that members shall be charged two dollars ($2) per Part of Transactions of the Society, beginning with Part I of Vol. 18 (1923). For further information on this matter see page 261 this issue of THE JOURNAL.

Part II of Vol. 15 (1920), the two Parts of Vol. 16 (1921) and the two Parts of Vol. 17 (1922) will be sent, without charge in addition to payment of respective dues, to members on request, if request is received by the Society within 60 days from date of notice to order.

A notice to order Part II of 1920 Transactions was mailed to the members on March 20, 1922.

The printing order will be based on the number of copies ordered by the members.

Copies cannot be guaranteed to members who do not order them on or before May 20, 1922

If you want a copy of Part II of the 1920 Transactions and have not already sent an order for the same to the office of the Society, please tear out and mail the coupon printed below promptly.

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
29 West 39th Street
New York City

Please enter my order for a copy of Transactions Vol. 15, Part II (1920).

....

Date S. A. E. Member

A Service-Man's Critical Estimate of Automotive Engineering

By B. M. IKERT[1]

CHICAGO SERVICE MEETING PAPER *Illustrated With* DRAWINGS

AFTER generalizing on the need for greater consideration in automobile design for service and maintenance requirements, the author discusses the accessibility of car parts at some length with the idea of pointing out difficulties encountered by service-station mechanics when parts are inaccessible, this having a bearing also on the length of time required for repair work and the consequent increased cost to the car owner.

Specific instances are given and illustrated in which improvements in design could be made to obviate trouble. These are inclusive of cylinders, cylinder blocks, pistons, bolts, cap-screws, nuts, valves, dashboard instruments and general take-up adjustment. Special emphasis is placed upon certain inaccessible parts that necessitate excessive dismantling.

IT is gratifying to those engaged in the maintenance of automotive vehicles that designers are giving more attention to accessibility of the units in the modern motor car. We are beginning to see the day when car parts will be so accessible that one unit can be removed readily without necessitating the disturbance of other units. The time will come when a car owner will not be required to pay a bill of some $35 to have a 10-cent Woodruff-key put into a shaft and gear. Cars now are being built so that a relatively inexperienced mechanic can make a coupling replacement on a magneto or distributor drive without danger of upsetting the timing. It must be made possible for a mechanic to get at a repair job in a normal working position in the cars to come, as against a condition requiring him to twist his body and arms into almost unbelievable shapes. Operations that formerly required 4 hr. to do must be cut in half. It may mean only the changing of the position of a bolt to make it more accessible, or the provision of a little more room between any two units to allow a mechanic to get at the parts.

Much has been said and written of late about the fixed price or flat-rate system of selling service to the car owner. It is not within the province of this paper to discuss the flat-rate system, except, perhaps, to mention that it is rapidly getting a good foothold throughout the Country and it would not be surprising to see it used universally within the next 3 or 4 years. However, it is certain that the general adoption of the flat-rate system can be hastened greatly if automotive engineers and car builders will design and build their cars so that justifiable prices can be established readily for any given operation.

One of the chief difficulties with many of our cars at present is that on a comparatively insignificant repair job many hours of labor are required to remove and replace units before the job itself can be done and the car turned over to the owner. Under such conditions it is extremely difficult for a service-station to establish a fixed price that seems commensurate with the nature of the job. How, for instance, can a service-man explain to a car owner that 23 hr. of labor was necessary to take up the wear in a rear main-bearing on one of the popular-priced cars, whereas it should be but a matter of about 3 or 4 hr. ordinarily? The time element in making repairs is important. Very often, the parts to be installed cost only $1 or $2, but the time required to install them is so great that the price for the work is out of proportion. One finds frequently in analyzing this situation that the car makers could so materially reduce the time element for service operations on their cars, by spending a few cents more per car, that automobile dealers and service-men would not need to resort to all sorts of means in trying to keep customers satisfied with their cars. Interference of parts has been the chief obstacle in getting certain repair jobs down to a reasonable time-basis, and many a service manager has had to make an endless amount of explanation for this to some irate car owner. Someone has said that "Knowledge of the other fellow's job leads to a better mutual understanding." Perhaps there is a direct application of this in the case of the automobile engineer and the automobile-dealer's service-man. The easiest thing for the service-man to do is to antagonize the product of the engineer and, likewise, it is easy for the engineer to criticize the service-man for his apparent lack of ability to do repair work properly. Both are right at times.

All of us realize that there are many intelligent service mechanics in the automotive business, men to whom automobile dealers are indebted for holding the good-will of their customers. Many of these men have enough engineering knowledge to be able to analyze the faults in a car intelligently and do it in such a way that the owner of the car will not be completely disgusted over having bought it. Service mechanics have to tear-down and rebuild cars day in and day out and, in the course of their work, they naturally come into contact with certain things in the construction of cars that are troublesome. A mechanic of great experience said a short while ago that the best thing the factories ever had done for the dealers' service departments was to make good liars out of the men employed therein. Perhaps this man overstepped the mark somewhat; his point was that the mechanics, while they realized well enough the faulty construction or inaccessibility of certain units, would not and could not tell the car owner about them for fear of putting future sales in jeopardy.

ACCESSIBILITY

It is impossible in a paper of this kind to consider the entire structure of a motor car and attempt to cite good and bad points of design as they affect accessibility in

[1] A.S.A.E.—Editor, *Motor Age*, Chicago.

repair work. It is realized fully that to change existing constructions on some of our cars would mean almost a complete retooling of the factory; the installation of new jigs, fixtures, dies and the like. Therefore, any criticism in the following paragraphs which may be directed at engines or cars is offered with this point in view. The major thought is to indicate the things of which service-station mechanics complain most frequently, when they have to tear-down or reassemble any of the units. It is likely that we shall never have 100-per cent accessibility in our cars. A motor car is made up of just so many necessary units and, if we make some certain one accessible, this probably will have been done at the expense of the accessibility on some other. Also, certain units may seem very accessible at the time of assembling the chassis in the factory but, when body and fenders are added, the reverse is true. It is this condition with which the service-station has to deal. Recently, I looked at an engine that was very accessible out of the car and when in an engine stand but, when in the car, the engine was hung so low and had so many accessories heaped around it, such a multitude of wires, control rods, carbureter hot-air pipes and the like, to obstruct the movements of the mechanic, that all the efforts of the engine designer to get accessibility were nullified.

Some 25 items peculiar to a considerable number of American cars are touched upon in the following paragraphs. These were chosen at random and exist in varying degree on other makes of car. Some of the things discussed cannot be classed under the general head of either accessibility or inaccessibility, and yet they are problems with which the service mechanic must come into contact more or less every day.

Opinion has been prevalent among repair-men, service mechanics and cylinder regrinders during the last year or so, that the blocks have not been allowed to age enough before machining them. The same is true of cylinder-heads. Naturally, the result is a warping of these parts when the car is put into use. The chief offenders along this line seem to be the six-cylinder engines, wherein the blocks are fairly long and therefore apt to distort more than would be the case with a shorter block. Those who are called upon to do much cylinder work in service-stations state that one of the chief difficulties with the small six-cylinder engine is the ineffective cooling of the cylinder walls at certain points. Referring to Fig. 1,

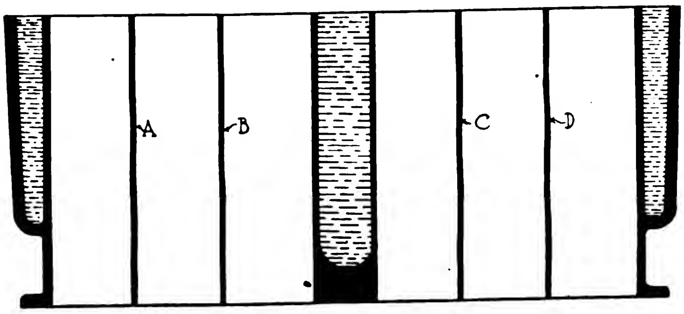


Fig. 1—Section of a Six-Cylinder Block Showing How the Metal at the Points A, B, C and D Warps Owing to Heat and the Lack of Water Space

Fig. 2—The Wear of the Cylinder Wall Is Lessened Where the Piston Extends Above and Below the Bore and the Latter Arrangement Gives the Oil a Chance To Be Shaken Off the Piston

it is seen that the water surrounds cylinders Nos. 1, 3, 4 and 6 more completely than it surrounds Nos. 2 and 5. The result is that the metal of the walls at the points *A*, *B*, *C* and *D* gets hotter in proportion to the other parts of the walls; consequently, it is apt to buckle slightly. This condition is made more aggravating in a green block, and a service-station mechanic obviously has much difficulty in trying to solve such a problem when the car probably has not gone over 1000 miles. This, then, is a case in which the manufacturer must do his part, either by sufficient aging of the blocks or by heat-treating them, which is costly. A service-station mechanic may be ever so good a workman, but he can do little with a twisted or distorted cylinder-block and, what is worse, he has a harder time trying to explain matters to the customer.

Pistons

In some engines the pistons do not come slightly out of the bores at their top and bottom positions of the stroke, and there is a tendency at times for the pistons to wear shoulders in the top and the bottom of the bores as shown in Fig. 2. The wearing of these shoulders is accelerated when the piston cocks in the cylinder, due to warpage, misalignment and other causes. Some engine designers are fitting longer pistons to offset this and, in addition, they are bringing them above and below the cylinder bores. Further, it is claimed that bringing the piston below the bore offers a good chance for excess oil to be whipped-off of the piston-skirt. Naturally, the service mechanic is not in a position to change existing design conditions in an engine but, if the maker gives the right thought to cylinder blocks, pistons and rings, the service-man is much better able to cope with so called oil-pumping engines, the fouling of spark plugs, and the like.

Bolts, Cap-Screws and Nuts

In tracing out some of the more flagrant cases of inaccessibility, we find that thousands of dollars and hours of labor could be saved annually in the upkeep of cars if makers would locate bolts, cap-screws and nuts so that mechanics could use speed-wrenches on them more readily. A double-end wrench generally will do better work than a monkeywrench, but the speed-wrench that has a socket incorporated in it to fit over a nut or cap-screw completely is best of all, not only in securing a good hold but in reducing the time required to remove or replace it. The most common difficulty in this connection is that bolt-heads or nuts are placed too close to fillets or to surfaces running at right angles to the top and the bottom of the nut, as shown in Fig. 3. This means that a mechanic

cannot get at the nut or bolt with a socket-wrench and therefore must use something else. This is made especially difficult where nuts are exposed to mud and water, as they are on front-axle spring-clips. A recent test on the removal of nuts, which had become more or less rusted to the clips, showed that it required almost 2 min. to remove the nut with a double-end open-wrench. On another car, where the layout permitted the use of a socket-wrench, the same size of nut was removed in less than ½ a min. There are other places on the chassis where nuts and bolts are placed in positions awkward to reach. Thus, cases are on record where spring-bolts cannot be reached with either an open-end or a socket-wrench because of the interference of mufflers, brake-operating rods and the like. In one instance the maker had not provided sufficient opening in the running-board splasher; so, to remove the bolt in the front of the rear spring it was necessary to take off the running-board and splasher. The hole in the splasher was just large enough to permit lubrication; it would not allow the complete

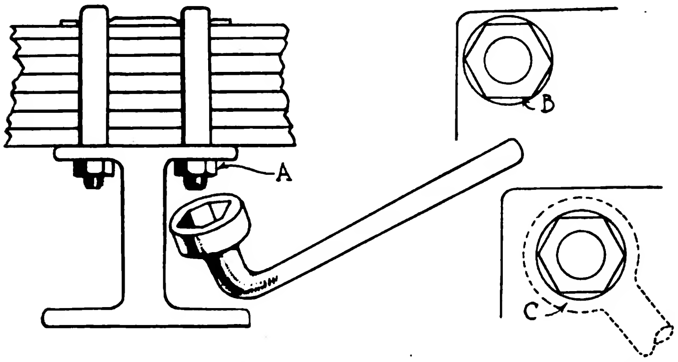


FIG. 3—TOO LITTLE CLEARANCE FOR SOCKET WRENCHES IS PROVIDED AROUND CAP SCREWS AND NUTS IN MANY CASES

withdrawal of the bolt? How can a repairman explain to a customer that it is necessary to charge him for removing and replacing the running-board and splasher to install a new bolt?

VALVE ADJUSTMENT

One of the most frequent jobs in a service-station is that of valve adjusting or grinding. Valves are accessible in general, except that the valves at the extreme ends of the set on some L-head engines are so close to the walls of the valve-chamber that adjustment is difficult because the mechanic cannot give a good swing to the wrenches. Fitting a longer valve-chamber cover would allow the wrenches to sweep over a wider range.

DASHBOARD INSTRUMENTS

When the word "inaccessible" is mentioned to a service mechanic, among the first things he thinks of are the disposition of the instruments on the dash and the manner in which they are connected. It would cost but a few cents more per car to install somewhat longer wires on the switch, ammeter and fuse-block, slightly longer copper tubing on the oil-gage and longer choke wire; but this would mean a vast saving of time in the service-station, because it would permit the mechanic to remove the panel usually having the instruments mounted upon it, withdrawing the whole assembly to a comfortable working position, such as is shown in Fig. 4. As it is now, a mechanic must twist his body into every sort of a shape to get behind the instrument-board. It is even worse when there is a tank in the cowl because, very often, the tank must be removed. It seems that a hinged

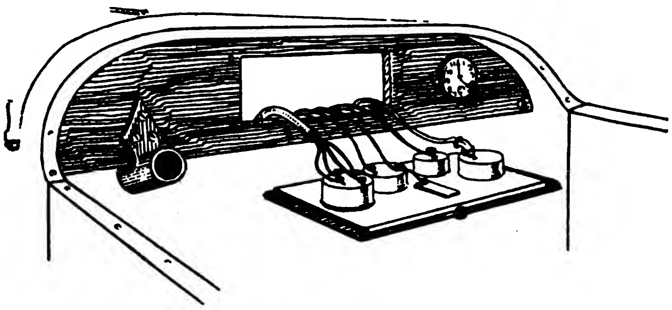


FIG. 4—THE USING OF SLIGHTLY LONGER WIRES FOR THE INSTRUMENTS SO THAT THE WHOLE ASSEMBLY CAN BE WITHDRAWN AND WORKED UPON WOULD PROVE ADVANTAGEOUS

instrument-board is worthy of consideration by the car builder, because it would make it unnecessary even to remove the instruments to inspect them. It would not be necessary to have the entire board on hinges; in fact, part of it probably would need to be kept stationary to support the steering-column as is done in most cars now.

In connection with making the wires more accessible, mention is made of the desirability of alloting definite colors to certain electric circuits, so that the same circuit could be identified readily on every make of car, once a man knew which circuits the colors indicated. As it is now, it is difficult for a mechanic to trace out a circuit when there are from 5 to 8 wires coming out of a piece of circular loom, all wires having the same color and appearance. Wiring diagrams are not always available and the problem often becomes acute in shops where all makes of car are worked upon. For instance, as shown in Fig. 5, if a mechanic knew that all black wires designated the starting-motor circuit; red wires, the ignition; green wires, the lamp circuits; yellow wires, the generator, ammeter and battery circuits; and blue wires the horn circuit, his problem would be lessened immeasurably. Many will recall that in former years one maker of an ignition system used red, yellow and green wires on the magneto and coil, and that the units were marked with the letters *R*, *Y* and *G* to show just where the connections were made. Some makers are using colored insulation on the wires for the various circuits, but no attempt has been made at standardizing the colors for all cars.

GENERAL TAKE-UP ADJUSTMENT

Much of the work in a service-station is devoted to eliminating squeaks and rattles, some of which are difficult to locate at times. One car has a tube extending across the frame at the rear of the car. On the inside of this tube is a rod threaded at both ends so that the whole

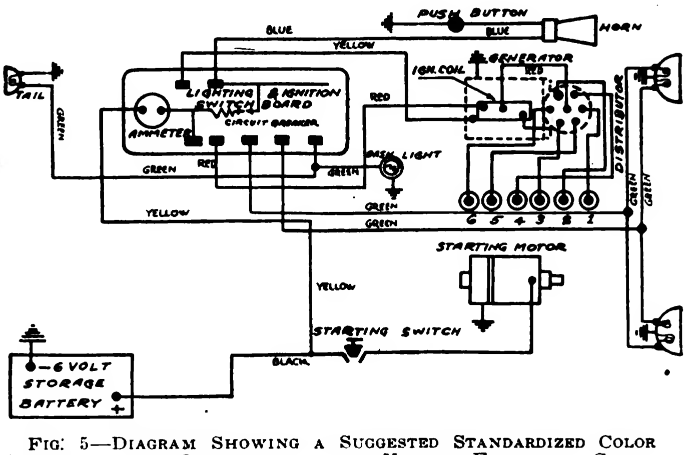


FIG. 5—DIAGRAM SHOWING A SUGGESTED STANDARDIZED COLOR SCHEME FOR THE INSULATION OF THE VARIOUS ELECTRICAL CIRCUITS

assembly can be tightened by drawing up on the nuts on the outside of the frame. The tube also supports the tire-carrier. There is just enough play between the rod and the inside of the tube so that the rod vibrates at certain car speeds, strikes the walls of the tube and, because the tire-carrier acts much like a sounding-board, sets up a decidedly unpleasant rattle that is very difficult to locate. A slight kink given to the rod overcomes this.

Body squeaks are common, but frequently they can be overcome by tightening the body bolts. Here, however,

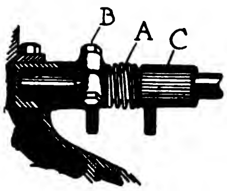


FIG. 6—BRAKE ROCKER SHAFT CONSTRUCTION SHOWING A GOOD EXAMPLE OF MEANS FOR TAKING UP RATTLE
The Slight Longitudinal Play between the Shaft and the Tube Also Insures Good Lubrication

difficulty sometimes is encountered in that the maker has used common carriage-bolts sunk into the body sills. The nuts on these bolts often get rusted in place and, when the mechanic attempts to tighten or slacken the nut, the entire bolt turns and there is no way for the mechanic to get hold of the head of the bolt. Sometimes the bolt can be reached but, in such cases, nothing is gained unless a square-head or a hexagon-head bolt is used. In most cases, also, the body bolts extend through the top flange of the frame only. This often makes the use of a socket-wrench impossible, especially when units like the muffler are placed alongside the frame at this point. Where a body bolt is extremely difficult to get at, a hole drilled in the bottom flange probably would allow quick access to the nut.

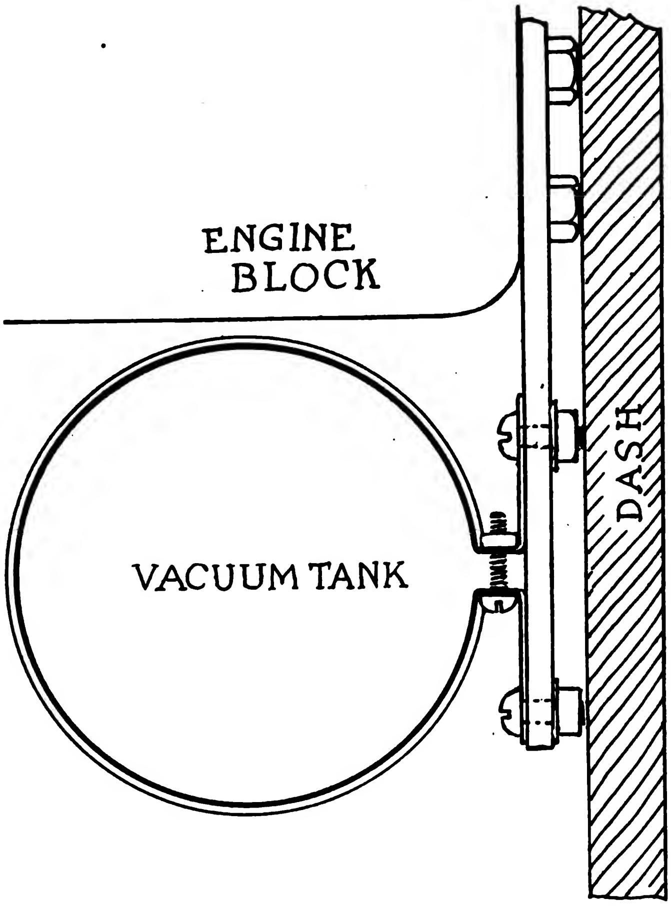


FIG. 8—AN EXAMPLE OF HOW THE DASH-BOARD INTERFERES WITH ATTEMPTS TO REMOVE THE VACUUM TANK

FIG. 7—SOME TYPICAL EXAMPLES OF FAULTY CAR DESIGN FROM THE VIEWPOINT OF THE SERVICE-MAN
In Many Cases the Steering Gear Cannot Be Removed Because the Gear Housing Strikes the Engine Crankcase. The Tightening of Body Bolts Is One of the Repairman's Chief Difficulties because the Entire Bolt Turns when the Nut Gets Rusted on. In One Car when the Temperature of the Atmosphere Is About 30 Deg. Condensation Caused by Warm Air Coming Up Through the Distributor Shaft Housing and the Cold Air by the Fan, Takes Place in the Distributor Housing and Water Must Be Wiped out about Every 30 Miles. Brake Bands Are So Thin on Some Cars That when They Are Relined Each Blow of the Hammer Produces a Flat Spot. The Illustration in the Lower Right Corner Shows a Rod Placed Inside of the Tube That Often Causes an Annoying Rattle and One Difficult to Locate

Fig. 6 shows the method used by one company to overcome rattle in the brake-operating shafts. Here a shaft is placed inside a tube, the shaft operating one set of brakes and the tube the other. A coiled spring *A* is placed between the arm *B* attached to the shaft and the tube *C*. The result is that any end-play is taken up automatically. The slight amount of end-play existing and held in check by the spring further helps to lubricate the surfaces by virtue of the lateral movement.

Removal of the steering-gear is not the easiest job on most of our cars. The redeeming feature here is that this job is not frequent. The job of removal becomes relatively easy when the gear is mounted on top of the frame, but when mounted in the side of the frame the chief difficulty lies in the fact that the distance *A*, as

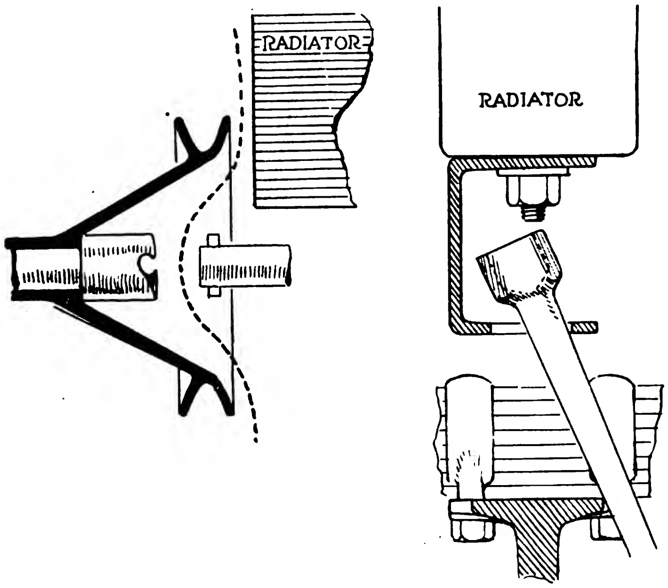


Fig. 9—Two Difficulties Frequently Encountered in Making Repairs on the Front End of a Car
In the View of the Fan Pulley Layout at the Left the Dotted Line Shows the Course To Be Followed by the Fan Belt in Putting It On. The Difficulty in Getting at the Radiator Fastening Nut with a Socket Wrench Is Illustrated at the Right

shown in Fig. 7 is less than the distance *B*. In other words, the engine does not permit the withdrawal of the gear-housing and the drop-arm shaft. The latter generally can be removed by loosening the engine in the frame or dismantling the gear.

We have seen much better brake layouts within the last year or so, and much has been done to make adjustments easier. However, one criticism of brakes is that some makers are inclined to use stock for the contracting band that is too light. This does not hold its shape as well as a heavier band; often, when brake-lining is riveted to such a band, the band will assume the shape of a polygon, caused by the hammer-blows at each point of riveting. Obviously, such a brake-band will not be as efficient as one which comes close to being a true circle when engaged with the drum.

Inaccessible Parts Necessitating Dismantling

Something might be said regarding the installation of vacuum tanks. It it difficult for service-men to understand why any maker should hide the tank in the cowl. Although vacuum tanks give very little trouble, there are times when they must be removed and there does not seem to be any good reason why the tank should not be mounted on the engine or at least on the engine side of the dashboard. The tank on one car is mounted in the

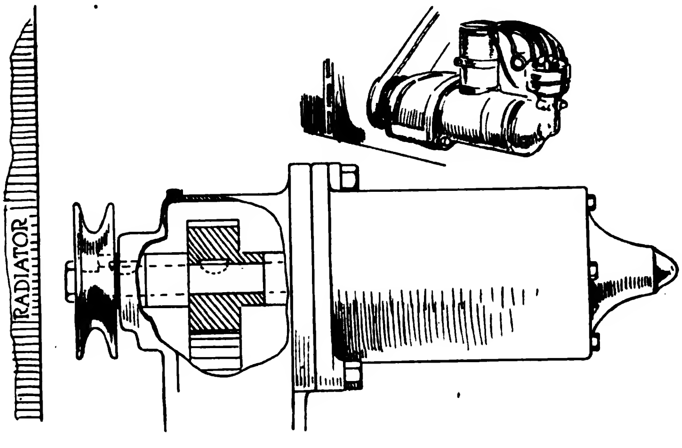


Fig. 10—Generator Layout on an American Car
In This Particular Case the Radiator Must Be Taken Off, the Fan Pulley and the Timing Gear-Case Cover Removed and the Gear Pulled before the Generator and the Shaft Can Be Pushed Out of Position

latter position, but the bolts have been located so inaccessibly that it is virtually impossible to remove the tank. This is illustrated in Fig. 8. The plan of mounting the tank on the engine seems to be working out very well, inasmuch as the tank vibrates with the engine in this case and there is little danger of having the fuel lines crack-off because of differences in vibration that often occur when the tank is located on the dash. Also, there might be a more general use of coils in the copper tubing to absorb vibrations.

Probably the greater share of service work is on en-

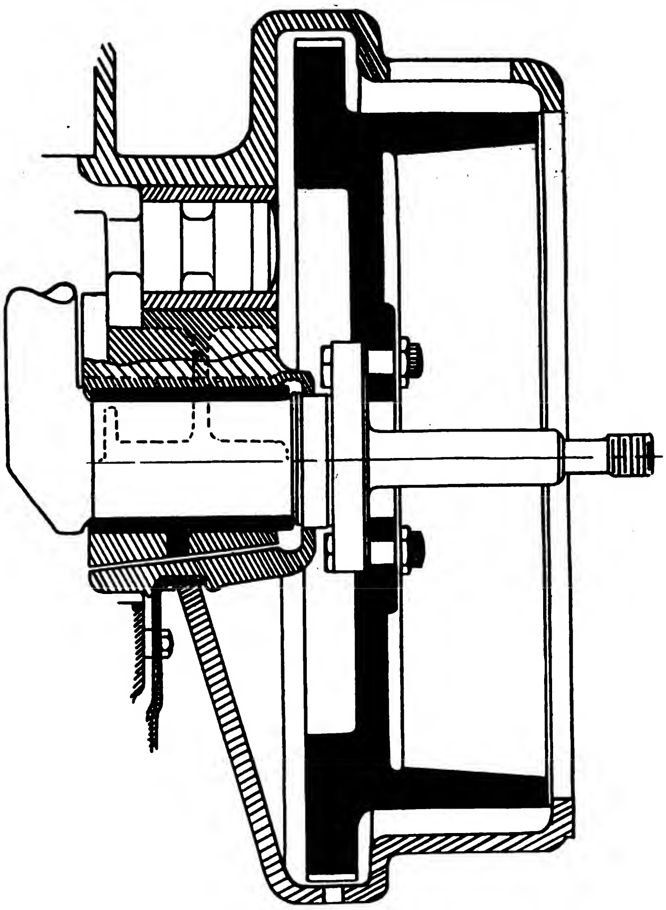


Fig. 11—Sectional Elevation of a Flywheel That Cannot Be Removed Until the Crankcase Is Dropped, the Connecting-Rods Disconnected and the Main Bearing Caps Removed

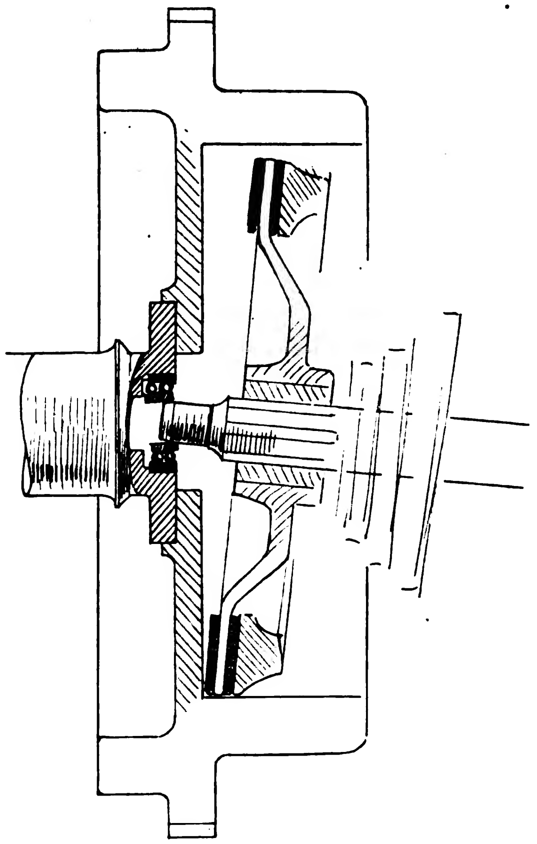


FIG. 12—IT IS DIFFICULT TO INSERT THE SELF-ALIGNING BEARING USED ON THE CLUTCH PILOT SHAFT BECAUSE THE BEARING TILTS IN THE FLYWHEEL

gines. A few cases will be cited in this connection in which a little thought on the part of the engine designer will be of great benefit to the service-station mechanic. The job of installing a fan-belt very often runs into considerable cost because of the slight clearance allowed between the fan pulley and the radiator. Fig. 9 shows this situation as it exists on one of the popular cars. The dotted line shows the course which must be followed by the fan-belt when installing it on the pulley. This car uses a heavy V-belt and there is insufficient room between the radiator and pulley to allow it to pass. This means the loosening of the radiator, which mechanics are loath to do on this particular car because of the difficulty of getting the nuts back on the radiator studs. The illustration shows why. A hole is provided in the bottom flange of the cross-member carrying the radiator, but a socket-wrench cannot be used because the hole is in a direct line with the I-beam of the axle. Consequently, the wrench enters at an angle and cannot strike the nut. The remedy seems to lie in using a longer bolt extending through the bottom flange, with a spacer between the two flanges.

On still another make of car the radiator must be drained, the hood removed, the radiator stay-rod disconnected, the hose connections broken and the radiator removed to take the generator off. This is necessary because the generator is mounted on the back of the timing-gear case with its shaft extending through the case and having the fan pulley mounted on the other end, as shown

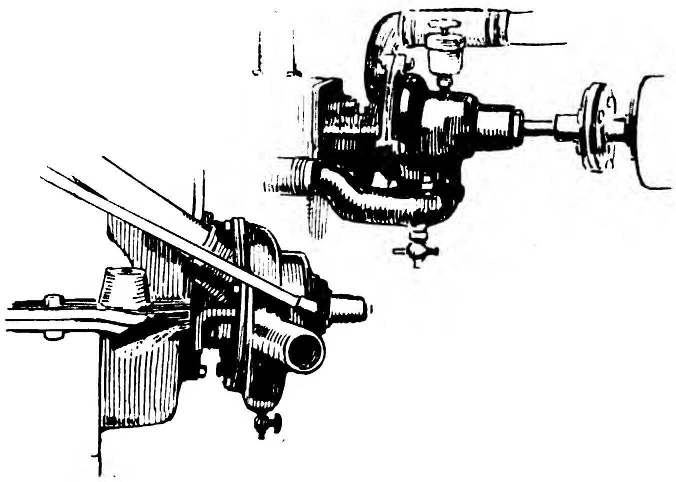


FIG. 13—TWO EXAMPLES OF PUMP INSTALLATION
The Pump at the Left Has Been Placed on an Extension of the Crankshaft and Is Difficult to Get At for Packing the Gland. The Pump at the Right Is Readily Accessible

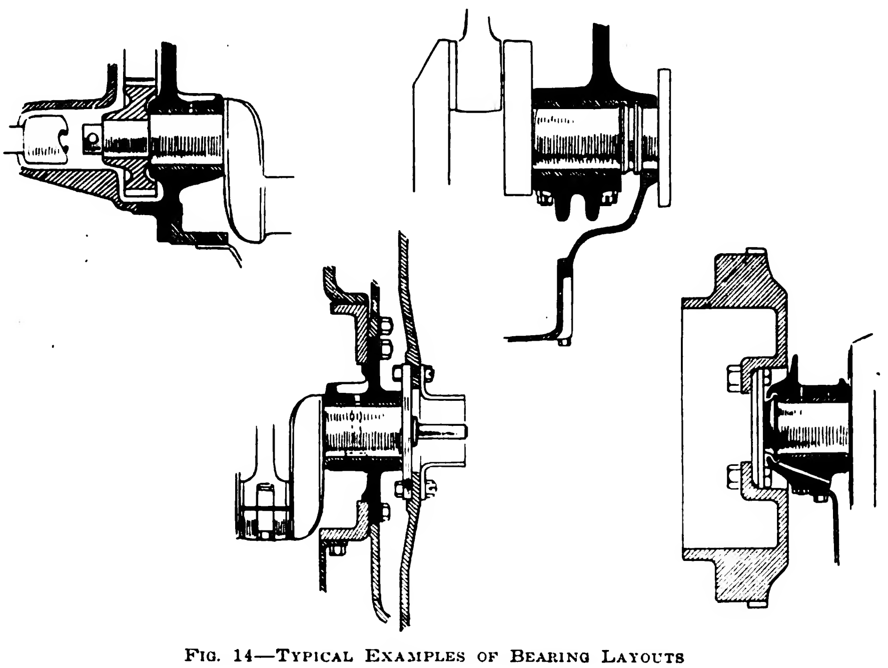


FIG. 14—TYPICAL EXAMPLES OF BEARING LAYOUTS

in Fig. 10. The fan pulley must be pulled off, and the generator drive-gear removed, before the generator can be slipped out of position. It appears that something like an Oldham coupling should be used between the generator and the drive-gear, so that the generator could be slipped out of position without affecting the other units. The reason the radiator must come off is that there is not enough room between it and the end of the shaft to allow the fan pulley and the gear to be slipped off.

On one engine used in a number of light cars, the main and connecting-rod bearing-caps must be removed and the crankshaft and flywheel dropped as a unit before the flywheel can be taken off. This was observed recently in a service-station where a car using this engine came in with several of the flywheel teeth stripped. Fig. 11 shows why the lower crankcase needs to be removed, the bearings disturbed and the shaft and the flywheel taken off together. The flywheel housing follows the contour of the wheel too closely and is further dropped at the open end, evidently to accommodate the No. 5 S.A.E. bell-housing. Even if the flywheel bolts are removed, there is not enough clearance to slip the wheel through the housing.

There is an instance of a maker using a self-aligning bearing in the flywheel as a pilot bearing for the clutch shaft. It so happens that, when a repair-man has to slip the clutch assembly into place, he cannot lift the rear end sufficiently to allow the clutch shaft to enter horizontally into the pilot bearing. The self-aligning feature of the bearing makes the job difficult because the bearing, that is the inner member, cocks and no amount of coaxing will help. Mechanics say that when this job is necessary they simply file the end of the clutch shaft enough to make a sloppy fit. This construction is shown in Fig. 12.

Some car makers seem to try to hide the water-pump as much as possible, thus making the job of repacking the glands difficult. Pumps often are placed too low on the engine, as in the left view of Fig. 13. Here the radiator really ought to come off to permit a good job when repacking the pump. The location of the pump shown at the right is good. The gland is very accessible and the unit has been mounted high enough on the side of the engine to make for ease of maintenance.

The job of getting at the main bearings on some engines is easy, but it is exceedingly difficult on others. For instance, it costs about $35 to take up the wear in the rear main-bearing on one popular make of car. The reason for this is that the bearing is of the split type and is held in an end-plate on the rear of the engine crankcase. To remove the bearing halves for filing, the entire engine has to be taken from the car, the timing gear-case cover removed, the crankcase gear pulled, the rods disconnected, the flywheel removed and the plate holding the bearing taken off. The crankshaft and rear bearing can be taken out then through the back of the

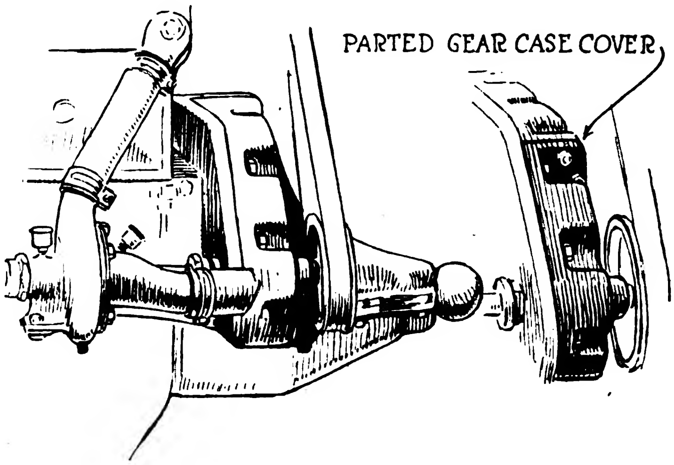


FIG. 15—PROVIDING A PARTED GEARCASE COVER TO FACILITATE DOING WORK ON THE PUMP DRIVE GEAR HAS REDUCED THE MAINTENANCE COST MATERIALLY

crankcase, and the bearing can be dismantled. It is small wonder that this job runs into money. The layout is shown in the lower left view of Fig. 14. No provision is made on this same engine to take up wear in the front main-bearing. This is a solid bushing indicated by the upper left view.

The illustration at the upper right shows the very accessible rear main-bearing layout used on a popular car. It will be noticed that the removal of the lower half of the crankcase brings the bearing cap into as accessible a position as could be desired. Another bearing layout that is difficult to get at is shown in the lower right corner. Here the flywheel shape and bolts do not allow the cap to come off unless the bearing bolts are raised sufficiently. The real job, however, lies in getting the bolts back into the holes, because a wire must be bent to take the heads of the bolts and the bolt heads must be juggled into position. Some type of flat-head bolt on the flywheel would help.

Fig. 15 shows how one builder made it possible to save many hours of labor on the job of putting in a new key on the water-pump gear. In the old construction it was necessary to take off the radiator, the entire timing gear-case cover and several other parts to get at the key eventually. The newer models are made with a parted gear-case cover so that only one end of it need be removed to get at the gear. This was a distinct step toward the saving of time and money on service.

Constructions that are good in one sense occasionally cause trouble in another. For instance, condensation takes place in the distributor at a certain atmospheric temperature in one car, so that the distributor housing has to be wiped out at certain intervals. It is said that this condensation is caused by the fact that warm air comes up through the vertical housing from the crankcase, while cold air from the fan strikes the exterior.

MEMBERSHIP ROSTER TO BE MAINTAINED IN PRIOR FORM

It has been decided by the Council upon reconsideration that the Membership Roster for this year shall be issued in the form in which it has been issued in previous years, including the Company and the Geographical lists as well as the Alphabetical List. It will be mailed to members upon receipt by the office of the Society of request forms that have been mailed to them twice recently.

The Value of Standards in Tractor Manufacture

By P. M. Heldt[1]

Minneapolis Tractor Meeting Paper

THE history of the systematic introduction of standards in mechanical manufacture is outlined, instances being given of the need for such standardization and specific reference being made to its value to tractor builders.

After mentioning the necessity of manufacturers maintaining a broad-minded attitude toward standardization, the author discusses steel and other standards, such as tractor hitches, belt speeds, connections between parts or machines that are made in different plants, screw sizes, lug attachment and general matters relating to the subject. The hope is stated that tractor manufacturers will appreciate the full advantage of cooperative effort and of mechanical standardization as one of its expressions.

THE movement for the systematic introduction of standards in mechanical construction is only about 20 years old, having started with the formation of the Engineering Standards Committee in Great Britain, about the beginning of the present century. There were many standards even before that time, such as measurement, screw-pitch, gear-tooth and rolled-steel-section standards, but these earlier standards were, so far as they related to manufactured articles, for the most part adopted individually in response to pressing needs, and did not constitute the result of concerted movements in standardization. The formation of the British Engineering Standards Committee may well be considered the first step in the organized endeavor to introduce standards in engineering practice. The second step was the inauguration of standardization work by the mechanical branch of the old Association of Licensed Automobile Manufacturers, which was continued by the Society of Automotive Engineers. The third step was the introduction of engineering standardization during the war period in practically all European industrial countries. One reason why we must standardize in the present stage of industrial development is that the builder of any complicated machine always buys raw materials from outside sources, and sometimes even completely finished parts. It is in the interest of economy and general efficiency that the purchased materials be such as can be bought in the open market, and that they do not need to be manufactured especially for the particular purpose.

Perhaps one of the most striking instances of the need of standardization is furnished by the rubber tire and its rim. The rim, being a metal part, usually is made by a different company from the one that makes the rubber tire. It is essential that every pneumatic tire of a given diameter and width of tread should fit every rim of corresponding dimensions to the end that when a motorist on tour ruins a tire shoe he can get another one of any make that may be available, so long as it is of the same diameter and width. The advantage to the motorist and to the general user of the machine is that his troubles in keeping the machine in operating condition will be lessened. Standardization is also highly desirable from the standpoint of the dealer, because it enables him to do a certain amount of business in a given time with a smaller stock. It is this phase of the movement that induced the Government to support it strongly during the war; there was then urgent need for conserving the capital resources of the Nation. It is obvious that the greater the variety is in which articles serving the same purpose are made, the greater the amount of capital must be that is tied up in stocks and in manufacturing equipment. Standardization appeals in a somewhat different way to the manufacturer who works according to the standards in his plant than it does to the purchaser of the standardized machinery. In almost every case it is the purchaser who profits most directly by the standardization. The manufacturer of the standardized article benefits indirectly, in that standardization enables him to give his customers increased value without additional cost to himself.

Magneto Mountings

Perhaps the best example of the value of standardization that can be cited to the tractor builder is that of magnetos and magneto mountings. The location of fastening holes in the base, the height of the shaft-center, the shaft-end and the overall dimensions of magnetos were standardized by the Society many years ago, and this standard is adhered to generally by the magneto manufacturers. The advantage to the tractor builder lies in the fact that, with possibly a few exceptions, any magneto on the market will fit his engine without special adaptation. If his regular source of supply should fail for any reason, such as a fire, strike or flood, he could arrange with any other factory to supply him temporarily with its product. Provided the mounting arrangements were in accordance with the S. A. E. Standard, he would have no difficulty whatever in mounting the new magneto and, if satisfactory terms could be made quickly, there would be no need of interruption in production. I believe that every tractor company using high-tension-magneto ignition makes use of this S. A. E. Standard. There could be no better endorsement of its value.

Regarding this plan of standardization, we can imagine the magneto manufacturer arguing that if it is so easy for his customers to substitute another magneto for the one he manufactures, it is not to his advantage because his hold on the trade will be loosened; therefore, that it is not an advantage to him to encourage standardization. There has been a feeling of this kind with respect to standardization in some industries, and it has been the cause of much of the opposition with which the movement has had to contend. But it is easy to prove that this attitude has a very weak foundation. The same standardization that makes it easy for a customer to change from one's own to a competitor's product, also makes it easy for him to change from a competitor's product to one's own; therefore, unless a manufacturer already controls the entire business and has no chance of getting any more, he has nothing to fear from standardization on this score. This point is borne out by the fact that all manufacturers of high-tension magnetos are using the S. A. E. Standard. A very direct advantage to

[1] M.S.A.E.—Engineering editor, Class Journal Co., New York City.

the magneto manufacturer in regard to mounting standardization lies in the fact that it relieves him of the necessity of manufacturing his machines separately for each customer. There are still slight variations in the demand, in respect to the direction of rotation, the position of the timing lever and the like, but these can be met readily. The machines are all alike, except for a few parts, which reduces manufacturing costs and permits of working for stock.

Steel and Other Standards

The steel specifications constitute another set of most important S. A. E. Standards that are being used by the tractor industry. There is now a general tendency to reduce weights in tractor design, and this means increased use of alloy steel in shafts, gears and similar parts. The alloy-steel industry has grown up with the automobile industry and is largely dependent upon it. No other industry uses alloy steel to anything like the extent that the automobile industry does; the statement was made recently that 70 per cent of all of the alloy steel produced in this country goes into automotive plants.

Alloy steels are made almost exclusively to the Society's steel specifications, and the parts manufactured from them are heat-treated accordingly. The standardization of steel specifications and of heat-treatments is conspicuous in the most valuable work that the Society has done. In connection with the published tables of physical properties, this standardization enables the engineer to select the steel best suited to any particular purpose and to specify a heat-treatment that best meets the requirements of the case. The work has not been limited to alloy steels; it covers carbon steels as well. Most of the drop-forged crankshafts and connecting-rods used in tractors are made of an S. A. E. steel. It is unnecessary to dwell upon this particular item of standardization, as the more extensive use of the Society's steel specifications by the tractor industry will come about naturally as the more primitive methods of construction, typified by the use of structural steel and cast gears, are abandoned.

Standard Hitches and Belt-Speeds

The greatest need for standardization always exists at the points of contact between the products of different plants. The tractor connects by a drawbar to the plow or other implement, and by a belt to the separator or other power-driven machine. Every tractor should be capable of connection to any plow or other implement, which necessitates standardization of the hitch; and every tractor also should be capable of driving by belt all the usual agricultural power machinery at proper speeds, which necessitates standardization of belt speeds. The height of the drawbar hitch has been standardized; this standard is used by many companies but not by all. A moderate variation in the height of the hitch is perhaps of no great moment, as the drawbar connections will compensate for it. The height of the hitch is adjustable on some tractors but, where this is not the case, it is advantageous to make the hitch of a certain standard height.

Belt speeds also have been standardized; in fact, the original standard has been revised already. The belt speed was fixed first at 2600 ft. per min., but it was found that a single speed did not meet all requirements. At present the Society has four standard belt speeds, and the National Association of Farm Equipment Manufacturers, formerly the National Implement & Vehicle Association, has five. It is possible that this number of different speeds is necessary temporarily because of the requirements of the various types of power-driven machinery now on the market. The designers of these machines had nothing to guide them in determining the pulley sizes. The result is that there is an absolute lack of agreement in the required belt-speeds. This condition can be remedied in the future. I believe that eventually there will be no need for more than two standard belt-speeds. The situation in this regard is somewhat similar to that in the pneumatic-tire field, and I believe the problem can be solved in the same way as was applied there. When a standard list of pneumatic-tire sizes was promulgated some years ago, it contained a certain number of sizes that were designated as definite standard sizes and a number of others that it was explained were to be continued by the manufacturers only while the replacement demand for them lasted. This served as a warning to car designers that new cars should be equipped only with the definite standard sizes.

In the determination of standard belt-speeds, there should be cooperation between the producers of tractors and of stationary farm-engines on the one hand and the builders of auxiliary machinery on the other hand, because the same agricultural machinery that is driven by tractors is driven by stationary engines. If, say, two definite standard belt-speeds were agreed upon, the designers of agricultural machinery would equip all new types of machine with pulleys calculated for one or the other of these speeds in the future, and the situation gradually would become simplified.

Standard Basic Machine Elements

One class of standards relates to materials of construction or basic machine elements. Of the standards of this class that were adopted originally for the automobile industry, many are now in use in the tractor industry. I need mention, in addition to the S. A. E. steels, only the standard non-ferrous alloys, tubes, screws, washers, pipe fittings and ball bearings. However, some of the standards of this class deserve wider use; for instance, the standard forged rod-ends and yokes.

There is a class of standards relating to the joints or connections between parts that are often made in different plants. The magneto standard already mentioned, the carbureter-flange standard, the bell-housing standard and others belong to this class. The value of these standards is so obvious that they have been adopted generally without hesitation; in fact, most of these standards were formulated at the request of parts manufacturers, and tractor builders had little to do with their adoption.

Screw Sizes and Lug Attachment

There has been some talk of reducing the number of screw sizes for use in tractors. It is easy to see why this would be an advantage. One of the difficult problems in connection with farm tractors is that of maintenance. A tractor cannot be transported easily, and all ordinary repairs must be made right on the farm with the facilities available there. In the use of tractors, screws and nuts are often lost or broken or have their threads stripped, and they must be replaced. It would be much easier for the farmer to keep a good stock of screws and nuts on hand if only a few sizes were used. In all the ordinary screw-standards the sizes vary in steps of 1/16 in. Why cannot the odd sixteenth sizes be eliminated in tractor construction? The direct benefit of simplification would not be limited to the farmer, but be shared by the builder and the repair-shop. There is one objection to the elimination of certain screw-sizes; for instance, in places where a 7/16-in. screw would just suffice, a ½-in. screw would

have to be used and the weight would be increased slightly. However, this disadvantage does not offset by any means the advantages to be gained, especially in view of the fact that with the use of heavier screws in some cases, a smaller number would serve the purpose. Very likely, different producers of tractors are now following this plan individually. If it has general approval, why not make it a standard or recommended practice?

Another subject that deserves the consideration of the tractor industry particularly at this time is the method of attaching lugs. Attention has been called to the tendency to reduce tractor weight, but to get sufficient traction with less weight it is important that the lug equipment be made as efficient as possible. Different operating conditions call for different lug equipment, and the farmer therefore finds it necessary to change lugs occasionally. With a standardized method of fastening, not only would the interchanging of lugs by the farmer be facilitated, but inventors of improved lugs would find it easier to market them. Considerable research is being conducted with respect to the best form of lug for different soil conditions. The minimum tractor-weight permitting a given drawbar-pull to be obtained depends to a large degree upon the lug equipment and, as the reduction of tractor-weight without any reduction of drawbar-pull spells increased efficiency, this development ought to be encouraged in every possible way.

General Considerations

Standardization really signifies cooperative effort on the part of members of the industry. Perhaps no industry needs this cooperative spirit more at present than the tractor industry. During the war and for the two years following it, this industry enjoyed a sort of hot-house growth that was the direct result of the high prices of farm products and the scarcity of farm labor. Conditions now practically are reversed. Farm products sell at abnormally low prices and help is plentiful. The farmer has very little money to spend, and he no longer has a prospect of an almost unlimited market for his products to encourage him to widen his scale of operations. In the past the desire to work an increased acreage was often the reason for the purchase of a tractor. Tractors retain all the advantages they ever had, such as the ability to work to full capacity in all kinds of weather and the lack of need for feed and care during periods of non-use, but their first cost and their operating cost must be reduced to conform with the changed economic conditions on the farms. Every builder is interested in this problem and all should cooperate to solve it.

While not a panacea for all the present woes of the tractor industry, standardization will prove a powerful aid in solving its problems. In this connection, no other branch of the mechanical industries today is producing as efficiently as the automobile industry. It is not a mere coincidence that this industry also has carried standardization further than any other. Efficient production really means large-scale production, because it is only in large-scale production that really efficient methods are applicable. It is for this reason that a large proportion of the firms that have entered the automobile industry in recent years confine themselves to assembling. Their own output may not be so very great, but all the components that they use, such as the engine, transmission, axles, steering-gear and the like, are made in parts factories, generally on a much greater scale. If it were not for the standardization work of the Society, this plan of assembling would be greatly hampered; in fact, it would become almost impossible. Much of the credit for the rapid advance in automobile design and for the efficient production methods now in use in the automobile industry belongs to these parts factories.

Summary

The three outstanding facts which should convince every tractor company that standardization is of value to the tractor industry are that

(1) This Country's largest industry of manufactured products has standardized to a great extent and is continuing this work
(2) The Government compelled standardization in many lines during the war, because of the economic advantages to be gained
(3) European industrial countries, impoverished by the war, are turning to standardization as one means of re-establishing their economic balance

The standardization movement would have advanced much further by this time had it not have been for the more or less natural tendency among members of an industry to regard one another with distrust. As a rule, it requires some event of a catastrophic nature to bring them together and make them see that they can accomplish more by pulling together than when each one works for himself regardless of the others. The automobile manufacturers were first brought into a close union by the Selden patent situation, which was a real bogy during the early years of the industry. Many other industries learned the value of cooperation during the war. The slump in farm values is undoubtedly the greatest shock that the tractor industry has had so far. It is hoped that at least some good will come out of the misfortune and that the tractor manufacturers will see the full advantage of cooperative effort and of mechanical standardization as one of its expressions.

HIGHWAY ENGINEERING AND TRANSPORT INSTRUCTION

The University of Michigan has made provision for a broad development of highway-engineering and highway-transport undergraduate and graduate instruction and for the investigation of research problems. Thoroughly trained and experienced highway engineers are needed to occupy the innumerable positions connected with the administration, financing, design, construction and maintenance of the 2,500,000 miles of rural highways and the thousands of miles of streets in the municipalities of the United States in order that the highways of our Country may serve efficiently the agricultural, industrial, commercial, social and military requirements of the Nation.

The phenomenal development of highway transportation in the United States has created a demand for men having knowledge of and trained in a new technical field. Fundamentally this branch of engineering deals with the science, art, economics and business of highway transportation of passengers and commodities. It is considered that the highway-engineering staffs of the Federal and State Departments will require an annual supply of 900 college-trained engineers, in addition to the highway engineers required by counties, municipalities, contractors and companies producing highway machinery and materials; that 4000 men should be trained in highway transport each year in universities to serve as motor-truck-fleet managers, sales-engineers, advertisers, business administrators and highway-transport engineers, and that short-period advanced courses efficiently provide opportunities for men occupying the positions enumerated to obtain a knowledge of and training in highway engineering and highway transport.

Passenger-Car Brakes

By J. Edward Schipper[1]

Annual Meeting Paper *Illustrated with* Drawings

STATING that the problem of deceleration is just as important and necessary of solution as is the one of providing car-acceleration ability, the author gives a comprehensive survey of present braking practice and outlines future requirements and possibilities.

Design factors are considered at length, as well as the subject of what constitutes uniform and effective braking-power, various illustrations and descriptions being included of different types of brake. Brake-actuating means, the calculation of brake-drum size, car-stoppage ability, brake equalizers and brake-linings are commented upon in some detail.

The future of brakes is discussed with reference to the use of the engine as a brake, four-wheel and front-wheel brakes, the servo principle of brake operation and various novel braking methods. A brief summary of what is considered good practice with regard to truck brakes is appended.

FOR the past 10 years automotive engineers have been concentrating very largely on acceleration. More than half of the development work on passenger cars particularly has been with the object of increasing the "get-away." Through the sales efforts of the industry, the public has been educated to demand this quality in an automobile. This is but natural when the quality of acceleration is what makes a car not only more enjoyable but more safe to handle in traffic, and certainly it is this same quality that makes a car a good hill-climber. However, in giving so much attention to acceleration, we have run somewhat ahead of the other problem, that is relatively just as important and just as necessary of solution. This is the problem of deceleration. It is just as important, if not even more so, to stop a car as it is to start it. It should be as much a matter for consideration on the part of the engineer that a car be able to get back to a standing position as it is that the vehicle be able to leap quickly from a standing start to speeds of 10, 25 and 50 m.p.h.

If we were to stop for a moment and take stock of the passenger cars and trucks put out by American builders today, we would find qualities of acceleration that are the marvel of the world. On the other hand, we would find qualities of deceleration that many consider to be deplorable. This statement is not made in a haphazard way, but is absolutely warranted by the engineering opinion of those who are responsible for our present day design. Scores of engineers of the highest standing in the industry have been consulted regarding the subject, in connection with the preparation of this paper, and the opinion is practically unanimous that our present-day brakes, if not the weakest, are assuredly one of the weakest points in design. To state this in another way, we cannot put the braking systems of the cars against problems of equal difficulty to those to which we submit other parts of the car and expect them to meet the same exacting requirements. We may send an experimental car out over the roads with orders to the tester in charge to try to break it up over a rough road and, if he succeeds, we believe that there is something wrong with the parts that fail.

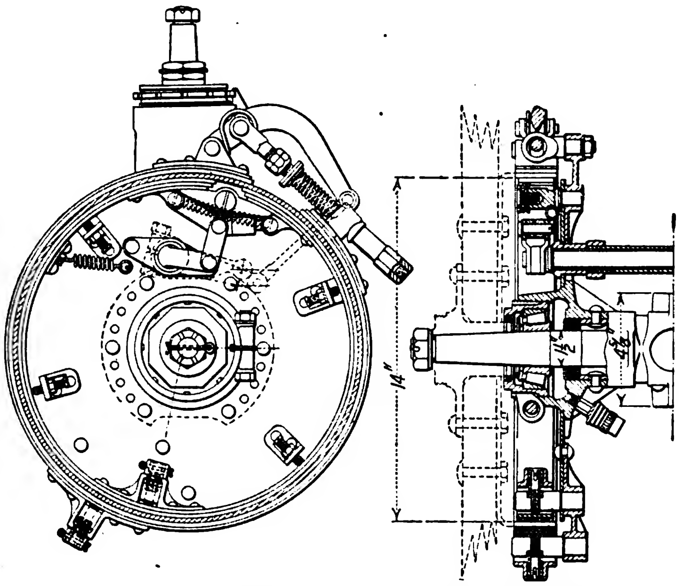


Fig. 1—Typical American Passenger-Car Brake Practice
A Contracting-Band Type External and a Toggle-Operated Internal Expanding Band Brake Are Used on the Same Rear-Wheel Drum

We may send him out to climb certain hills on high gear and, if he fails, we believe that the engine is not what it should be. But we do not send him out on steep, long hills with directions to try to burn up his brakes. We know too well that he would be only too successful. Whether this is a difficulty that we can rectify under our present system of brake design remains to be seen. The best brakes we have designed under present methods are inadequate in mountainous country, although they serve very well and efficiently in flat and moderately hilly country. When it comes to real mountainous country, however, the engine must be called upon to augment the brakes. Whether or not this is desirable is debatable.

Brakes of the Present

Every engineer desires to obtain the best possible results from the available braking systems, and it is hoped that hints will be found in this paper that will assist in increasing the efficiency of brakes as now installed, and that it will promote discussion leading to an airing of views as to whether it is necessary for us to modify our fundamental systems and change to something more efficient than we now have as usual equipment. When we give an automobile user a vehicle weighing all the way up to 3 tons, provided with an engine capable of accelerating that tremendous mass to high rates of speed in a very short space of distance and time, we are putting into his hands a veritable projectile capable of doing tremendous damage unless it is susceptible to easy control.

If we turn the problems of acceleration backward and look at them from a deceleration standpoint, we have something of the same nature to deal with. In accelerating, we are taking heat energy and transforming it through the mechanism of the car to dynamic energy as represented by the weight of the car and the speed at

[1] M.S.A.E.—Technical editor, Class Journal Co., Detroit.

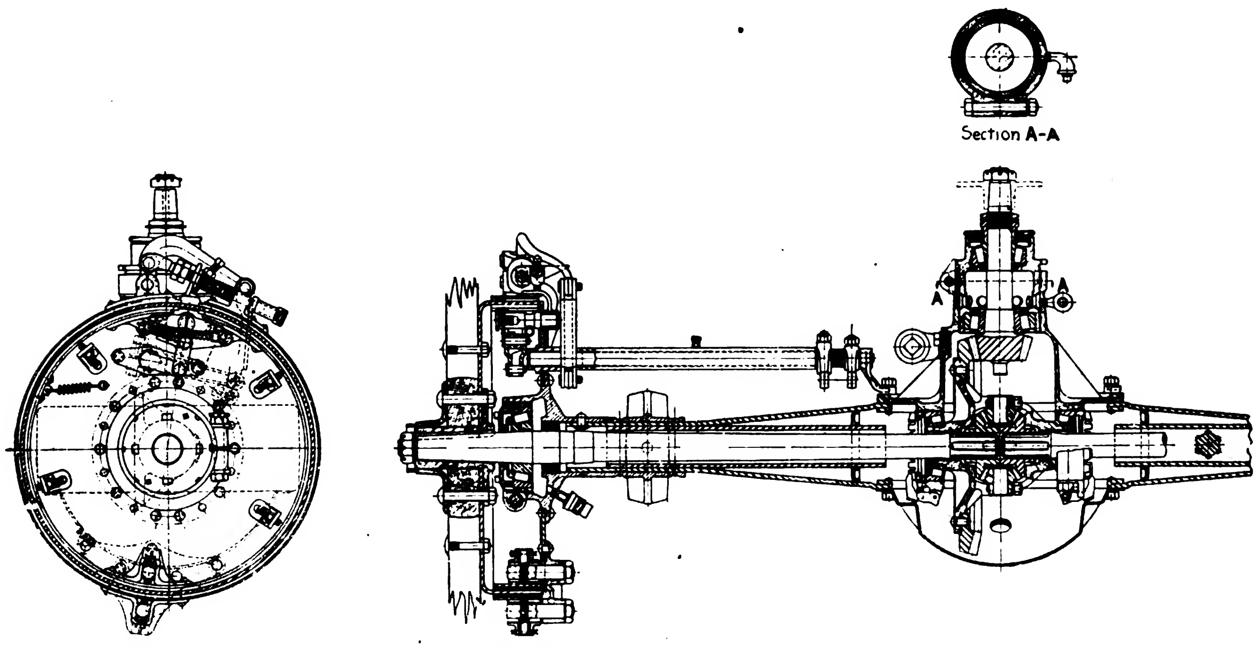


FIG. 2—A TIMKEN FIXED-HUB TYPE AXLE WITH AN EXTERNAL-CONTRACTING AND AN INTERNAL TOGGLE-TYPE BRAKE HAVING THE BRAKE LEVERS INSIDE THE SPRING

which it is traveling. This dynamic or kinetic energy must be dissipated by transforming it back to its original condition of heat energy through use of the brakes. To bring the vehicle to rest, it is necessary to absorb its momentum by making it do work against friction, and this friction produces heat, of course, which must be dissipated. The friction brakes act, therefore, by dissipating in the form of heat the energy represented by the momentum of the vehicle. To accomplish this, they must produce the heat and radiate it to the atmosphere. It is evident that the radiation of the heat must be as rapid as possible, in order that the temperatures of the braking parts shall not rise above a safe value for the materials contained in the braking mechanism, particularly at the contact surfaces. Since there is an appreciable time-element in the radiating ability of any surface, it is clear that, with the ordinary braking-systems, there will only be a certain length of time before the brakes become overheated, because the heat generated is imparted to the brake-bands much more rapidly than the heat can be dissipated through the ordinary braking-systems now provided. The steeper the grade is, the more quickly the brake temperatures will reach the danger point. Many of the hills encountered in the Allegheny mountains, for instance, are sufficiently long and steep for this temperature to run above the capacity of the lining to withstand burning, with the result that is all too familiar to engineers. To sum this up in simple language, it is possible

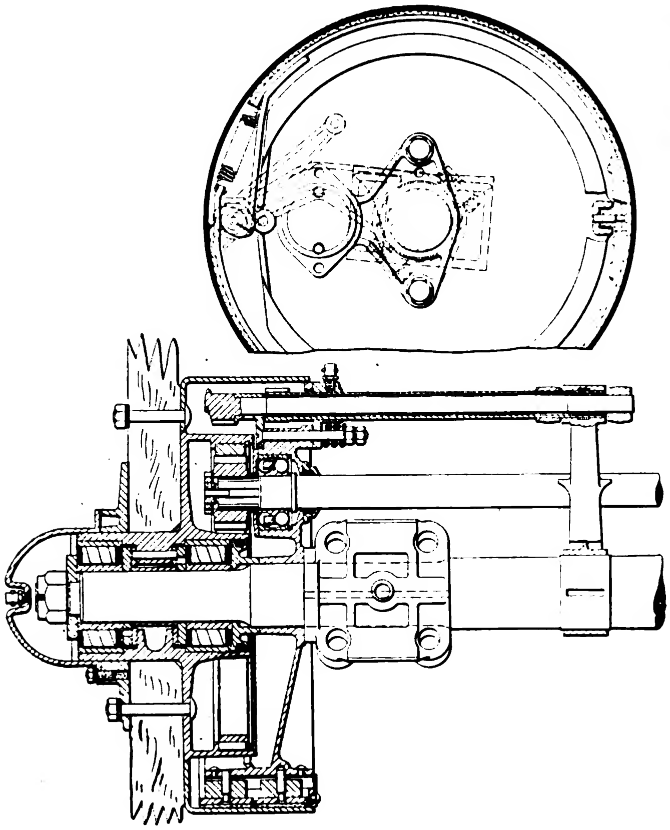


FIG. 3—DOUBLE INTERNAL-BAND TYPE REAR-WHEEL BRAKE HAVING AN 18-IN. DRUM THAT IS USED BY THE INTERNATIONAL HARVESTER CO. ON ITS TRUCKS

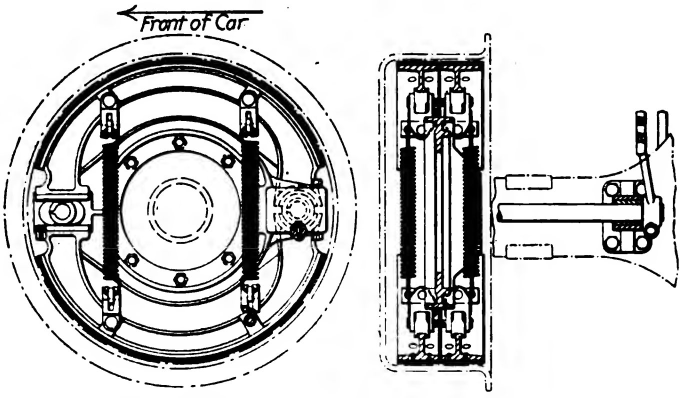


FIG. 4—DOUBLE INTERNAL CAM-OPERATED BAND-TYPE BRAKE USED ON AUTOCAR TRUCKS

to burn out the brakes on a car by using them in going down a long grade, provided the engine is not used to assist the brakes and we depend solely upon the braking system of the car.

Design Factors

When an engineer is laying out the brakes for a passenger car, assuming that he intends to work along the conventional lines, he has several different combinations and types of braking layout available from which to choose, under present conditions. By far the greater majority use two sets of brakes on the rear wheels, shown in Figs. 1 and 2, these being the internal and the external types, one set being operated by the pedal and the other by the hand-lever. This system is used widely because it has the advantage of simplicity and low cost of manufacture, and provided the brakes are laid out with

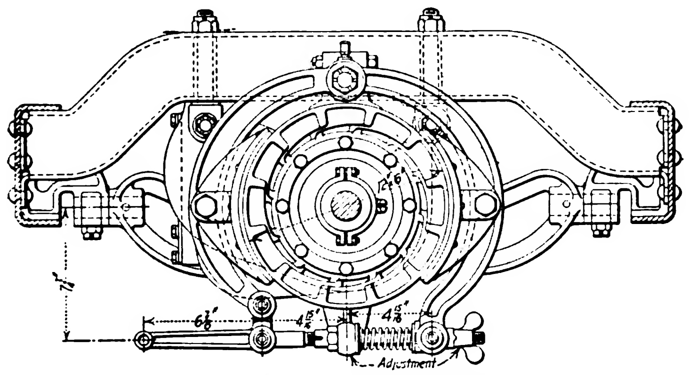


Fig. 5—Pierce-Arrow Truck Transmission Brake
This Brake, Which Is of the Contracting-Shoe Type, Has a Drum 12 In. in Diameter with a 5-In. Face

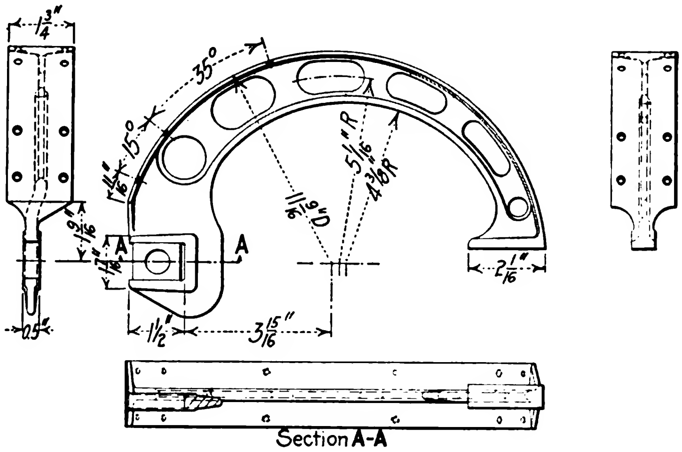


Fig. 6—Malleable-Iron Brake-Shoe of Rigid Construction for the Internal-Expanding Shoe Type of Brake

sufficient regard to proper brake-area and with the centers of the operating levers arranged so that spring deflection does not cause grabbing or releasing of the brakes, it is fairly satisfactory. In addition to this type of layout, we have the side-by-side internal brakes, illustrated in Figs. 3 and 4, which operate on the same drum, this having the advantage of providing two sets of enclosed brakes that are naturally more free from exposure to water, mud and grit. They are somewhat more complicated in assembly, however; they require a much deeper drawn-drum and probably never will be used widely because the complications introduced are not compensated for by any marked advantages in performance.

Another choice that has been favored by an increasing

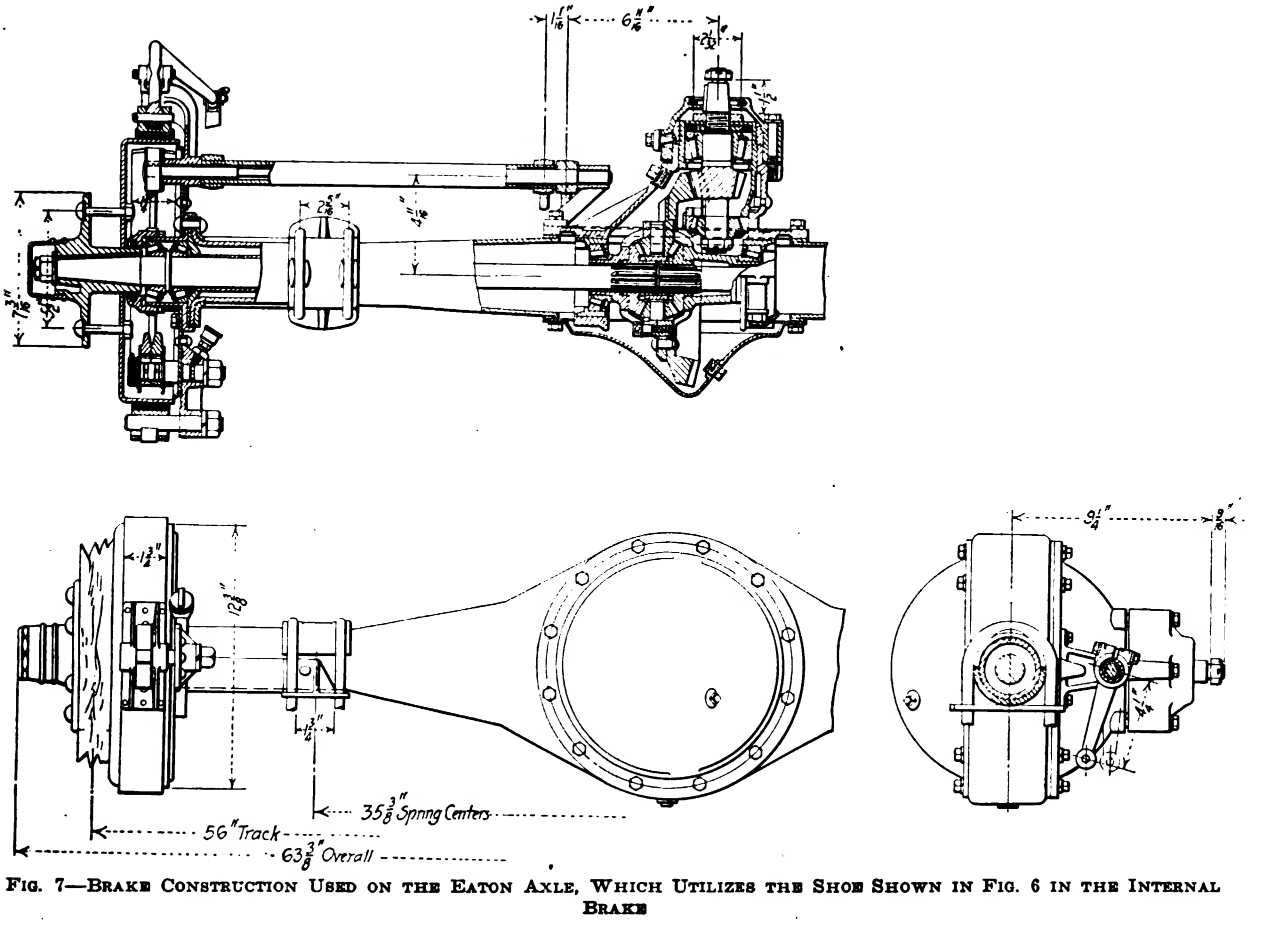


Fig. 7—Brake Construction Used on the Eaton Axle, Which Utilizes the Shoe Shown in Fig. 6 in the Internal Brake

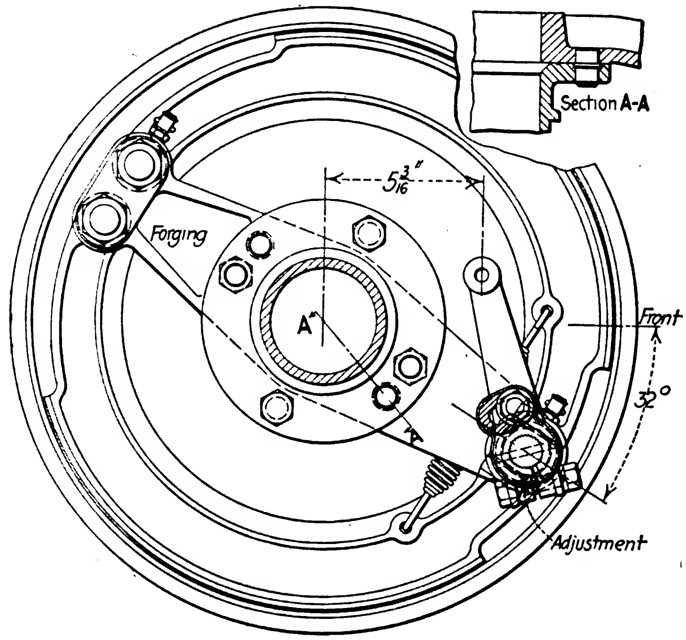


FIG. 8—REAR-WHEEL BRAKE USED ON THE PIERCE-ARROW TRUCK
This Is a Cam-Operated Type of Brake, the Cam Being Adjustable as Shown, That Uses a Heavy Forging to Provide a Substantial Brake Anchor

number during the past few years, after first having been used and discarded by several manufacturers, is the installation of the foot or service-brake on the rear wheel and the hand-brake on the transmission or propeller-shaft. This type, which is shown in Fig. 5, has the advantage of providing two absolutely independent brake-drums. In case one breaks, it does not affect the other and, furthermore, the installation puts into the hands of the driver a very powerful emergency braking-system. Because of the location of the brake on the propeller-shaft, the brake has the benefit of the reduction through the rear driving-system and also of the equalization secured by the differential-gear. The propeller-shaft brake has disadvantages, however; otherwise all manufacturers would use it. The disadvantages that frequently are cited against it are the tendency to chatter, the excessive stresses that must be imparted to the universal-joints and rear-axle parts and the difficulty of dissipating the tremendous amount of heat absorbed by the small brake-drum. Naturally, the size of the brake-drum is limited, because of the location of the propeller-shaft immediately under the floor-boards of the car. Most engineers have been partial to the wheels as being the proper location, because it involves stress in the least number of parts and hence is safer. In worm-drive and bevel-gear axles where the spiral angle is fairly steep, many of the pinion and worm-shaft-bearing failures have been the result of too severe propeller-shaft brakes. Overheating of the propeller-shaft brake is, of course, the point that is cited most against it.

After having determined the location of the brakes, the engineer has a choice of the flexible-band type of brake shown in Fig. 2 or the rigid-shoe type illustrated in Figs. 6 and 7. These again have advantages and disadvantages. The former is apt to have a tendency to grab severely, particularly at high speeds, on account of its wrapping action. With it, however, practically 100 per cent of the brake surface is effective. With any type of rigid brake-shoe, it is practically impossible to secure anything like effective surface for the full circumference of the drum. There are two classes of rigid-shoe brake; the pivoted or locomotive type and the simple type. In the former a separate brake-beam is pivoted to the shoe at its center, so that the entire shoe-surface is pressed against the drum. The greatest pressure is found to be under the pivot in this type, the pressure tapering off toward the end. If shoes of this type are made to cover 180 deg. of drum surface, the tips will present practically no pressure and from those points back to the pivot the pressure will gradually increase. This naturally causes unequal wear of the shoe facing and is apt to cause brake squealing because of the relatively small area of surface engaged. This cuts down the friction materially and, consequently, the brake efficiency.

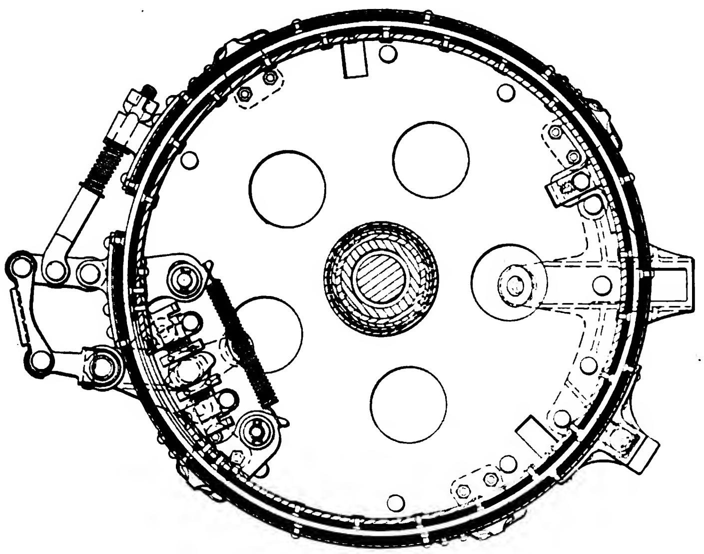


FIG. 9—DOUBLE INTERNAL AND EXTERNAL BRAKES USED ON THE MARMON CAR
This Is a Cam-Operated Internal-Expanding Brake That Is Anchored in the Usual Way with a Bell-Crank-Operated Contracting-Band Type on the Same Drum

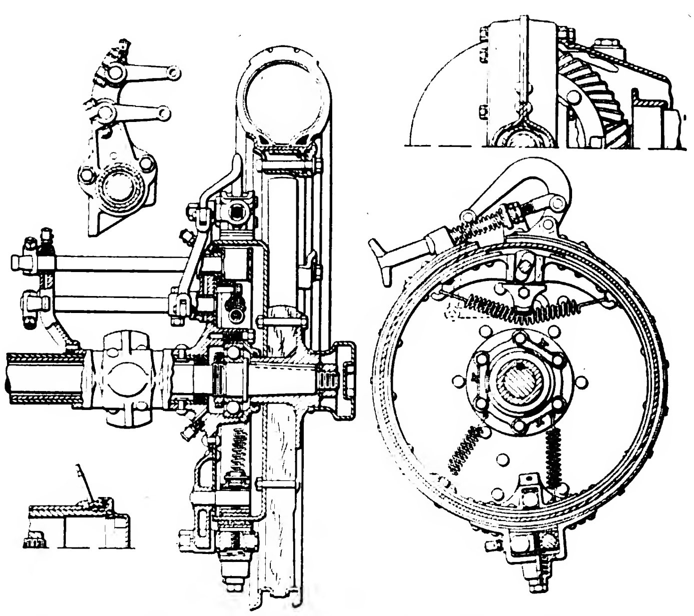


FIG. 10—DOUBLE EXTERNAL AND INTERNAL BRAKES USED ON THE PACKARD SINGLE-SIX CAR
The Internal Brake Is Cam-Operated and Substantial Release Springs Are Provided To Prevent Drag

In the simple type of rigid shoe, one end of which is pivoted fast to the spider, the other end being acted upon by the cam as in Figs. 3, 8, 9 and 10, or the toggle as in Figs. 2 and 11, the greatest pressure will be on that part of the lining closest to the fixed pivot and the pressure will taper off to zero at the tip. Unless specific provisions are made to the contrary, the movement of such a shoe will vary as the distance from the pivot, so that the portion of the lining closest to the pivot will have the greatest pressure if it is brought into contact with the drum, and still have so little movement that it may not establish the desired amount of contact and hence be ineffective. On the other hand, the portion of the brake near the other end of the shoe, being at the distance most remote from the fulcrum point, will have but very little pressure on the drum, the pressure it obtains being all

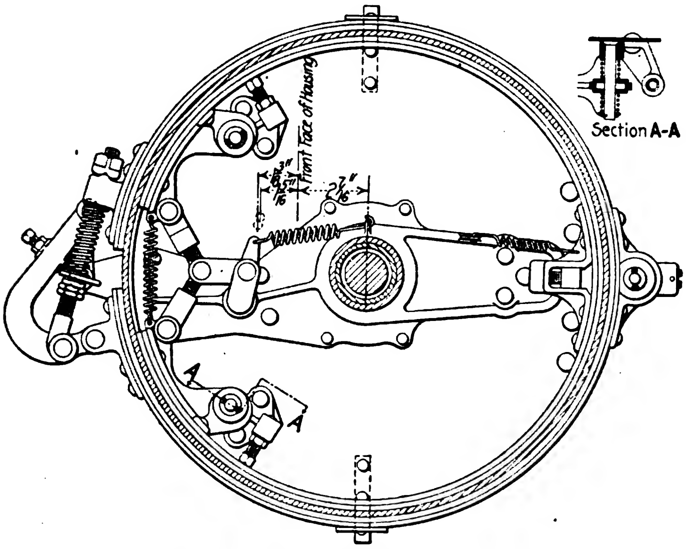


FIG. 11—INTERNAL AND EXTERNAL BRAKES USED ON THE LAFAYETTE CAR

The External-Contracting Band Brake Is Operated by a Bell-Crank and the Internal-Expanding Brake Is Actuated by a Double-Adjustable Toggle

from the direct action of the cam or toggle. To give full contact area, brake-linings should be cut back from the end of the shoe.

The question of using aluminum shoes for brakes is interesting. Some experiments have been made with them, without, however, reaching any real conclusion so far as I am aware. An experimental brake, equipped with an external contracting brake using a ribbed aluminum shoe instead of the ordinary external flexible band, has been tried out. The rib on this was of great height at the rear or middle where the anchor was located, and tapered down to almost nothing on the two forward ends where the contracting links were attached. Aluminum has the quality of rigidity and ability to radiate heat.

The other type of brake, examples of which are illustrated in Figs. 9 and 12, is based on the principle of a wrapping band that encircles the body entirely and against which the band is applied by force. It is evident that the pressure exerted on the rigid-shoe type of brake must be transmitted directly by the braking mechanism itself. Using the wrapping principle, however, if the true action is worked out, a maximum amount of brake resistance is secured by the action of the brake in wrapping itself up in the band. In this instance a very slight amount of force is necessary to bring the wrapping part into operation, and then the very action of

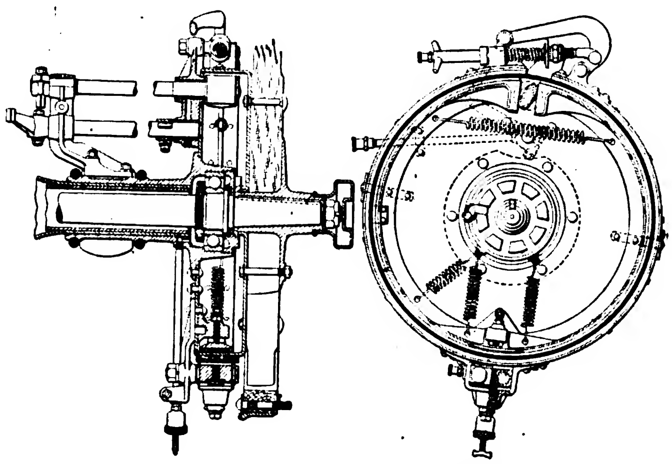


FIG. 12—DOUBLE INTERNAL AND EXTERNAL EXPANDING BAND TYPE OF BRAKE USED ON THE PACKARD TWIN-SIX CAR, THE FORMER BEING CAM-OPERATED

the moving body against which the brake-shoe works becomes in itself a generating force of power. This advantage of securing the maximum holding-power from a minimum amount of leverage and brake pressure recommends itself strongly to the engineer. Brakes should be equally powerful in both the forward and the reverse directions. This applies particularly to the wrapping-band type of brake. It is very apt to unwrap in the reverse direction, giving no braking action.

The point that it is desired to establish is that a brake having true wrapping action will give practically 100-per cent surface-contact, which, of course, is highly advantageous not only from the standpoint of effectiveness but from the standpoint of quietness in the brake action and the life of the lining. It is a well established fact that brake-squeal is due largely to concentration of the braking pressure on limited areas of braking surface. These high spots or contact points, being highly stressed, are caused to chatter and set up vibrations. There are many band-brakes in use today which, although designed primarily on the wrapping principle, do not really work out in this way. Instead of causing the operating levers of the brake-shoe to draw the band down snugly over the entire surface of the drum, the construction of the brake-toggles is such as simply to bring great pressure on the few inches of the brake-band near-

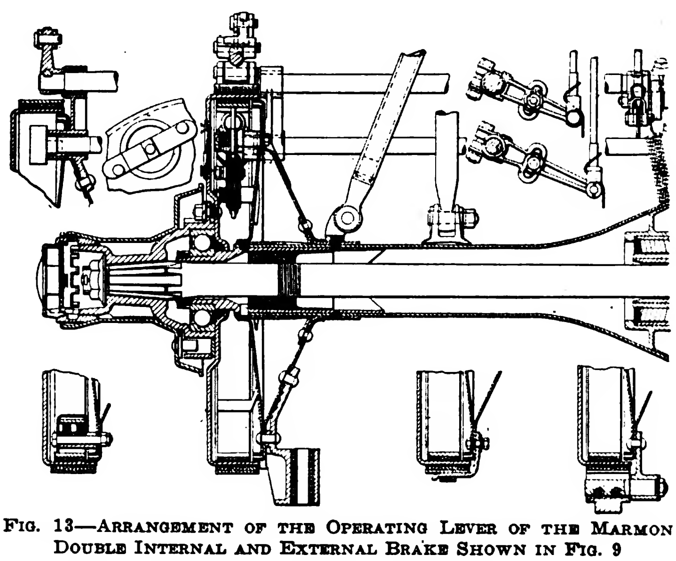


FIG. 13—ARRANGEMENT OF THE OPERATING LEVER OF THE MARMON DOUBLE INTERNAL AND EXTERNAL BRAKE SHOWN IN FIG. 9

The Width of the Band of the External Service-Brake Is Much Greater Than That of the Internal Hand or Emergency-Brake Band

est the toggle, and the rest of the brake-shoe, which probably represents nearly 75 per cent of the braking area, is doing very little or no work.

External brakes for passenger cars can be used with lighter drums than internal brakes because the expansion of the drum, due to heating, does not reduce but rather increases the power; whereas, internal brakes have insufficient travel on the levers to follow up the increased circumference. Neither does the distortion of a thin drum noticeably affect the power of the brake in contrast with internal brakes which, except in the wrap-up internal type, rarely fill the circumference of the drum, and especially in the case of internal-shoe brakes where practically no more than half of the drum circumference is utilized. In such cases the drum must be stiffened or ribbed to minimize distortion. Exposure to dirt and sometimes a rather unsightly appearance are objectionable features of the external brake. The cheapness of manufacture and upkeep has been responsible largely for the popularity of this type of brake on passenger vehicles. The external brake is, of course, very accessible. Consequently, it is used as the foot-brake because of the relative ease of relining and to reduce the cost of upkeep.

Uniform and Effective Braking-Power

To secure uniform and effective braking-power, the operating levers of the brake should be of such construction as to not only draw the brake-band by a wrapping action against the entire surface of the drum, but the operating principle should be such as to draw this brake-shoe band down with uniform pressure on the brake-drum, as is brought out in Figs. 13 and 14. If, when the brake-pedal is pressed down and the operating levers of the brake-shoe begin to tighten, the pressure of the brake-shoe is 50 per cent more on one side of the drum than on the other, it is obvious that the effectiveness of the brake has been lowered greatly, and the condition created that is apt to cause the squeal that is giving so many builders of cars much anxiety at present. It is only necessary to examine old brake-shoes to illustrate very clearly the points to which reference has been made. Engineers who have examined the brake-lining from several different makes of car have found that the following conditions apply. If the brake-shoes from one make of car are examined, it will be found that the lining is worn down to the brake-shoe for possibly 3 or 4 in. from the end of the brake where the toggles are operating. The wear on the face of the steel band grows gradually less as the hinge part of the brake is approached. When the hinge point, which is the fixed point from which the brakes operate, is reached, very little wear will be found. This is because there is not sufficient travel actually to make a firm contact, as has been pointed out. On examining the brakes taken from another make of car, it may be found that they are worn through to the steel band on one edge of the shoe and that on the other edge at least 1/32 in. of lining remains. In this case either one of two things has happened; the steel band was not correctly drawn and the steel is thicker at one edge than the other, or the operating mechanism of the band does not draw the band down evenly so that it gets an even pressure against the brake-drum at both edges of the band.

Another condition that will be found is that the brake-bands are not worn at the ends, where the toggles are, or at the hinge-point to a perceptible extent, but that they are worn through to the steel at a point about one-half way between the hinge of the brake and the operating toggles. This condition is due purely to an imperfect arc of a steel band. The band either has been bent or sprung, or it never was shaped-up so as to conform to the circumference of the brake-drum against which it was intended to work. Another point of weakness is that when the adjustment of the brake is too close to the drum the blowing-in of sand on a sandy, dirty road can create objectionable friction between the surfaces of the brake-shoe and the drum. There is no perceptible drag while the car is clean, but as soon as a sandy type of road is encountered, considerable drag is introduced.

Drag is due also to insufficient strength of the releasing mechanism; or the action of the brake may not be adequate to insure a proper release of the brake-band from the drum when the brake-pedal is released by the driver, as shown in Fig. 10. When the car is new, it may work very nicely; however, traveling in the dust and mud of the road for some months often has the effect of causing the parts to work heavily. It is not uncommon for the springs used to release the brake-shoes to prove inadequate for their work, and this results in a drag on the car, premature wear on the face of the shoe and often the generating of sufficient heat to blister the paint on the brake-drum. A brake-drum should be very well fitted and run true. Many brake-drums run out over 1/64 in. and, as the clearance between the liner and the brake-drum is generally less than this amount, the brake-lining is in frequent cases rubbing continuously.

Exposed and Protected Types

From the standpoint of heat radiation, the exposed type of brake is evidently best on account of the ability to secure air circulation and consequently more rapid heat-dissipation. Unfortunately, however, especially on rear-wheel applications, the open type of brake is subject to the severe drawback of exposure to water, dust and grit. Because of the composition of the brake-linings, which are heat-resisters primarily, practically all of the radiation is from the drum and, naturally, the most efficient radiation is secured when the entire outer surface of the drum is exposed to the air. With reference to heat radiation from the drum, it would be very hard to imagine any worse condition possible than that obtained in the conventional internal and external types of brakes used on the majority of passenger cars and on many of the lighter trucks. No more efficient insulation could be imagined than the two asbestos linings, one applied within the inner and the other on the external surface of the drum, when both sets of brakes are engaged. For normal driving over level country, such a system is all that is necessary, of course, because the length of time of brake application is insufficient to raise the temperature of the drum beyond a safe value. On the other hand, as soon as cars equipped with brakes of this type attempt to negotiate any long, steep hills, relying on their brakes alone, they get into trouble. In other words, it is perfectly possible to burn out the brakes on even the best of our passenger cars on a trip say over the Lincoln Highway from Philadelphia to Pittsburgh, where the long, steep grades of the Allegheny Mountains must be encountered. The motorist has only one resource and that is to use his engine for a brake. If he fails to do this, or does not know how to do it, his brakes will fail. It is only necessary to go into this part of the Country on a hot summer day to find that the air around the bottom of these hills fairly reeks with the aroma of burning brakes.

Side-by-side internal brakes, which allow the external surface of the brake-drum to be exposed and, consequently, permit more rapid radiation, are only a partial solution of this problem. The brake-drum becomes heated upon the application of one set of brakes for any

considerable length of time, of course, and there is no great advantage in being able to alternate the use of the two braking system, since both sets in use are compelled to operate against the same hot drum. Another drawback to the double internal-brake is that, unless the manufacturer has been unusually careful, there is a tendency to sacrifice brake-shoe widths on this type of brake layout to accommodate the widths of the drum without getting too deep a brake-drum flange which, of course, requires an exceptionally deep draw in manufacturing the pressed-steel drum. Two concentric drums on each wheel would separate the two braking systems entirely from each other, of course, but introduce complications that lead to rattles and possibly even structural weakness. Furthermore, the inner drum is apt to be of insufficient diameter and, consequently, the inner brake of insufficient surface-area. It is very difficult to design a brake of this kind that is not too light to have sufficient strength and still be crowded into the necessarily confined space provided. In addition, the inner brakes will be very apt to have insufficient radiating surface on account of the insulating effect of the outer brakes. To obviate the use of the single drum for the two sets of brakes, one is forced to consider the propeller-shaft brake, or front-wheel brakes, of which more will be said later.

Brake-Actuating Means

The placing both the service and the emergency brakes on the inside of the drum has an advantage besides that of heat radiation. This is the greater protection from dirt, as can be seen from an examination of Fig. 4. However, objection is that in the case of both sets of brakes it is necessary that they be cam-actuated. Some engineers believe that cam-actuated brakes are apt to be not positive. This is a debatable point. Where only one internal brake is used, the toggle construction can be utilized.

Brake-actuating means are so well known that there is no need of discussing them in this paper. The practice on the external contracting type is practically universally in favor of the pivot anchor directly opposite the contracting mechanism. The brake segments are formed with eyes for the anchorage joint or the steel bands have a fitting that is riveted to them to serve the same purpose. The brake support consists of a bracket secured to the rear-axle tube or to the radius-rod. The contracting mechanism is nearly always a floating bell-crank lever similar to that shown in Fig. 11, to the short arm of which one end of the brake-band is connected by a riveted bracket, while the other end of the band connects through a short link to the fulcrum of the bell-crank. The operating rod is connected to the long arm of the bell-crank. The short link is hinged to the free end of the brake-band and passes through the fulcrum pin, the bell-crank being forked at the lower end. A butterfly nut is screwed over the end of the link and provides a convenient adjustment. The adjustment is locked by the spring surrounding the link, which forces the arms of the bell-crank over the flat end of the wing-nut, thus preventing it from turning. The coil springs help at the same time to release the band when the pressure is taken off the brake-lever. This method, while offering a simple and efficient means of applying the brakes, has also the advantage of providing a simple adjustment means.

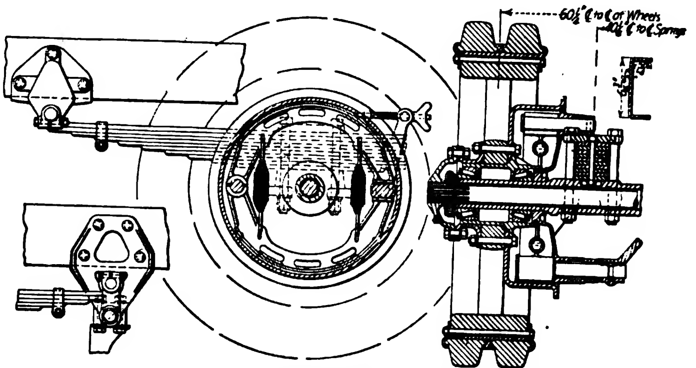


Fig. 15—Cam-Operated Internal-Expanding Shoe-Type Brake Used on the Rear Wheels of the Mack Truck

The operating means for expanding brakes are of four types; the cam as shown in Fig. 15, the toggle illustrated

Fig. 14—Brake-Rod Assembly and Layout of Linkage for the Cole Car Which Employs a Double Internal and External Brake on the Rear Wheels

in Fig. 11, the wedge and the double-arm lever. In the cam type the internal shoes are pivoted opposite the expanding point. An expanding cam is placed between two flat surfaces or is contoured to fit a follower surface that permits spreading the shoes apart to secure their contact with the drum. The toggle expanding mechanism also is employed very frequently. In this the ends of the brake segments are connected by a pair of toggle-links from the joints of which another link runs to a bell-crank whose shaft has a bearing in the brake-supporting bracket. Sometimes one or both of the toggle-links are adjustable. The toggle mechanism and the cam both have the advantage that they afford quick engagement at first, and then a slower engagement as the movement progresses. In other words, a greater leverage is obtained when desired and so is greater speed. The wedge expander is simply the action of a wedge that is forced between the two ends of the segments, spreading them apart in the same way as the cam, and the double-arm mechanism simply consists of two levers that throw over a center, forcing the ends of the segments apart when actuated.

Little need be said regarding brake releasing except that the anti-drag features on brakes should be sufficiently strong to free the bands or shoes from the drum positively on disengagement. There are too many instances of dragging brakes, due to having these made too weak for the purpose. The type of brake adjustment selected will, of course, depend on the design of the brake-operating mechanism. With some types of mechanism, such as the cam-expanders used in internal-expanding brakes, these adjustments are difficult to make. However, the question of adjustment is one of a detailed nature that is of great consequence in one or two particulars. In the first place, the adjustment should be extremely accessible so that the owner can adjust his own brakes or, if he needs to have them adjusted, so that his bill for this work will be as small as possible. Another important matter regarding brake adjustment is that it should be arranged so as to preclude much possibility of upsetting the layout of brake centers when it is made. It is very encouraging to note that there is a marked tendency to increase the diameter of the brake-drums even on the lighter cars. We have always had fairly good-sized brakes on our heavier and more expensive cars, but it is well known that this is a feature that has been neglected on the light and medium-weight cars, particularly those which sell for a low price. Few, if any, brake-drum sizes have been worked out by formula. Most of them have been made by guess-work at the start and increased gradually as complaints come in from owners and dealers as to the braking ability of the cars.

Formula for Brake-Drum Size

I have checked a formula that was worked out by a passenger-car engineer who had given the subject considerable attention. It gives results that are very good in the light of present accepted practice. The formula is

$$d = [(Wf \div 2w) + 1.5] \div \pi$$

where

d = Diameter of the brake-drum in inches

f = Factor of 0.045 sq. in., or the total effective service-brake surface per pound of the maximum weight of the car

W = Maximum weight of car and load in pounds

w = Assumed width of brake in inches

1.5 = Allowance for clearance between the ends of the brake-lining

The results of this can be checked against an area of 1 sq. in. per 17 lb. of car-weight. For example, applying the formula to the Ford car and assuming the total weight to be 2500 lb. with passengers and a 1½-in. width of brake-band, it will give a drum diameter of 12.4 in. or, say 12½ in. This would be about correct for this size of car. For another example, applying this formula to a large, closed car having a weight with passengers of say 6000 lb and a 2½-in. width of brake-band, it would give a 17½-in. diameter of brake-drum. Using the formula for other car sizes and weights, the results appear to work out very satisfactorily. A brake exercises its maximum efficiency when it is just short of locking the wheels. This has been demonstrated in railroad practice and is well known by experienced drivers.

Car-Stoppage Ability

It will be interesting to note what is considered good braking in the ordinary rear-wheel-brake application in stopping a vehicle. Table 1 has been taken from a test made on a car which, with passengers, weighed close to 4000 lb.

TABLE 1—REAR-WHEEL BRAKE STOPPAGE-ABILITY

Speed, m.p.m.	Distance Required for Stop on Actual Test, ft. in.	Standard Given by Thermoid Rubber Co., ft. in.
10	9— 0	9—2.4
20	34—11	37—0.0
25	53— 7	58—0.0
30	74— 5	83—3.6
40	135— 6.	148—0.0
50	178— 0	231—0.0

An allowance of 17 lb. of car-weight per sq. in. of brake area can be recommended for light and medium-weight cars; 20 lb. for heavier cars; and 30 to 50 lb. for medium and heavy trucks. Although the diameter of the brake is the main consideration in determining the holding power, since it determines the braking or retarding leverage, the width of the brake is a highly important factor. On the other hand, engineers should not be misled into putting too great a width on the brake, because of the difficulty to secure a full contact between the lining and the drum when the brake is new or when the lining is replaced. The engineer who recommends the formula that has been presented, after having determined the size of the drum (assuming that he is designing an internal contracting brake), lays-out the contracting mechanism so that the operating lever hangs down and the pull on it is in the opposite direction to that of the torque reaction. After having located properly the center of the eye of the operating lever as near the center of the torque-reaction circle as possible to keep the brakes from grabbing, the linkage is then laid out to produce a 30-lb. pedal-pressure to lock the wheels.

The linkage ratio generally is determined finally by experimenting. So far as we know, there is no formula that is reliable enough to recommend. Tentative linkage-ratios are first determined by assuming a 5-in. stroke at the pedal and juggling this with the stroke of the lever that operates the contracting mechanism on the drum, as determined by the layout. The cross-shaft location and the location of the center line of the eyes of the levers on the cross-shaft can be determined by making a half-size wood model of the main leaf of the rear spring, and this is fastened to the drawing on the board by wooden pins and shackles representing actual conditions. Fastened to the wooden single-leaf spring is a simulation of the rear-axle with the location of the brake operating-lever eyes. The model is then moved upward and downward a distance representing the maximum deflection of the spring. The curve of the movement of the lever eye

is then easily plotted; the curve for torque reaction also can be plotted; and from these data it is easy to determine accurately the proper location of the centers of the eyes to the levers on the cross-shaft. This layout can be checked experimentally by bolting a metal shield to the frame of the car between it and the brake-drum, to which drawing paper is glued. Pencils, held against the paper by spring plungers, are located in the same planes as the operating-lever eyes and, when the car is driven, trace the actual movement of the lever eyes for torque reaction and spring deflection. These curves are then checked against the curves determined on the drawing-board layout and the levers and their locations are then determined finally. The engineer who uses this method states that it has never failed to produce a good braking-system.

The subject of proper layout for the brake linkage is a large one in itself. This matter was covered very fully in a paper on the Correct Location of Brake Levers,[2] by Walter C. Baker, of the Standard Parts Co., that he presented before the Cleveland Section. With the Hotchkiss drive this is a very important matter, and is now receiving the consideration it deserves, although a few car builders have realized the importance of it for some time. It is a fact, however, that an alarming percentage of automobiles having the Hotchkiss type of drive gives a very unsatisfactory brake-action over a rough road. I have noticed some extreme cases where the links have been far off from the desired center. In one particular instance, when driving a certain car not long ago, the pedal moved through 3 or 4 in. of travel when running over extremely rough roads, and actually applied the brakes. When attempting to apply the brakes over roads of this kind, the wheels would alternately lock and release as the obstructions in the road were encountered, causing a tremendous chatter to be set up that not only made driving very unpleasant, but was extremely hard on the tires as well as on the entire structure of the car. Mr. Baker described in his paper the use of a simple measuring-device that permitted locating the proper center for the link-eyes. This center should coincide with the center of torque rotation and the center of spring flexure so that little or no pedal-action can be caused, either by the flexure of the springs or by the torque reactions in the rear-axle tube to which the brake support is connected.

An important point that should be taken into consideration in determining the position of the operating levers is that the pulling levers should all be arranged so that they will start in the longest position, or at approximately 90 deg. in relation to the rod, and end their movement at the shortest radius and with angles greater than 90 deg. The pulled levers are arranged to start operating at their shortest radius and end their movement at the longest radius with an angle of approximately 90 deg. when the brakes are applied. There is a general belief that the best results can be obtained by the use of brake-rods having front joints that are as nearly as possible in line with the front pivot of the radius-rods or torsion-tube, where used, or with the front spring-eye of the rear spring in the Hotchkiss-drive arrangement. Good results can be obtained when the rear ends of the rods are joined to brake levers at the back of the axle, instead of at the front as shown in Fig. 16. In this position, the radius of their motion is longer and, consequently, the chord of the arc through which they travel in response to spring action is flatter, producing less push-and-pull effect. This position sometimes has the advantage of placing the rear ends of the rods where they are more accessible for adjustment. To emphasize this point of adjustment it must be pointed out that poor adjustments often will spoil a good brake-layout. The burden of blame, however, should be borne by the designer, because of his failure to provide adjustments that are more nearly fool-proof. The brake-adjustment means should be simple and accessible so that the operator can keep the brakes properly set-up. It should be possible to take up wear on a brake by hand, without the use of any tools, the adjustment being made so as to be self-locking and proof against loosening from vibration or road shocks.

[2] See TRANSACTIONS, vol. 14, part 1, p. 657.

BRAKE EQUALIZERS

Regarding brake equalizers, there are two directly opposite schools; one believes that brakes cannot be equalized commercially, and the other uses brake equalizers as stock practice only on the service brake, generally, but sometimes on both. The reasons given by both sides are very interesting and cast some light on the entire question of brake-linkage layout. Some of those who do not use equalizers believe in equalization, but think that it is secured inherently in the mechanism that they employ, without a special equalizer-bar. Equalization is secured by some of the companies through use of cross-shafts that are sufficiently long and flexible so that they will spring enough to distribute the pressure. This has the advantage that in case rods, pins or any parts break or become loose on one side, it will not cause the other brake to be inoperative. An interesting reason that has been cited against the use of equalizers is that if they are not used and if oil collects on any one of the brakes and then the brakes are applied, greater braking is received from this wheel than if an equalizer were used. There is doubtless a great amount of difficulty in getting equalizers to work so that they will be absolutely certain. For this reason they have not been used by many firms. One builder states that it is possible to obtain a set of equalizers that work perfectly before the car is painted and never work afterwards, or be very satisfactory after the car is painted but go out of commission after the first piece of dirt gets into the brake-shaft bearing.

The question comes back to whether the equalizer can be made a commercial proposition. There is no doubt that a perfectly equalized brake is better than one that is not equalized, the matter being more of a commercial one as to whether brakes can be equalized so that they will remain so under service conditions. Of course, without equalizers it is absolutely essential that a very careful adjustment be made in the brakes so as to have both take hold with equal strength. When cars are not equipped with equalizers, there is a tendency for a brake to take hold at one wheel only if the adjustment is not proper. The result is that this wheel is often swung backward into the center line of the axis of the car. In other words, if the brake that holds be the rear right brake, the rear end of the car would have a tendency to swing to the left, an action that is dangerous at high speed or over slippery roads.

Some of the constructions of the equalizing-bars are very ingenious. They must be made rattle-proof but at the same time capable of taking all the stresses of brake application without noise. One company in the low-priced field uses two equalizing-bars as well as four pull-back springs hooked to the rear axle. The result has been a low-priced installation, particularly in view of the fact that it has been necessary to run the brake leverage inside the frame with this design. It has been found

economical by some to put the equalizer on the rear axle. This eliminates the necessity of having to employ a more extensive construction near the center of the car. One of the best compensating devices is the portion of a differential gear that has been used for years on the Rolls-Royce and has been seen on one of the higher-priced American cars brought out within the last 2 or 3 years.

When all phases of the matter are considered, it is found possible to get good results with either equalized or unequalized brakes. The question is really one of commercial practice rather than actual mechanical preference. An objection to unequalized brakes is that if the connections to the brake on one side are a little stiffer than the connections to that on the other side, the brake on the freer side will release before that on the tight side, tending to cause skidding. This condition is in rare cases so exaggerated that the freer side will release enough to allow the pedal to come back to the stop without releasing the tight brake. This naturally will cause the

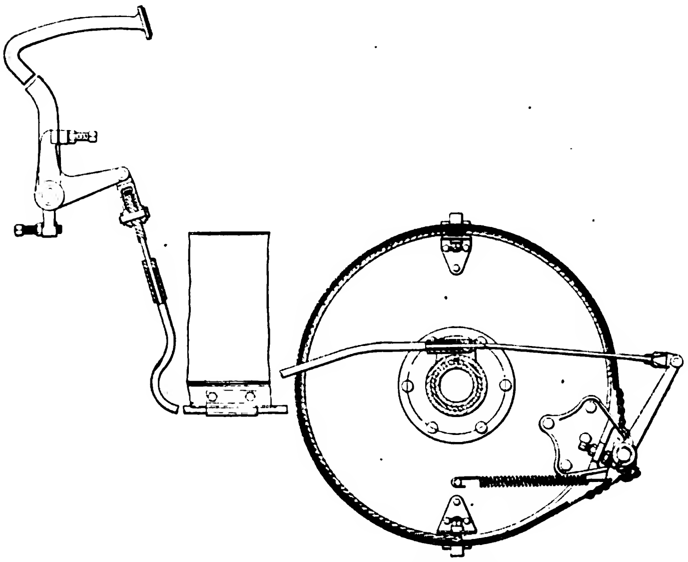


FIG. 16—CABLE TYPE OF SERVICE BRAKE USED ON THE LEXINGTON CAR
The Position of the Operating Lever Behind the Axle and the Accessible Adjustment Should Be Noted

dragging of one brake, with an increased fuel-consumption and unnecessary wear on the bands.

Some recent installations of cable equalizers, an example of which is illustrated in Fig. 16, are interesting. Care should be taken against stretch and excessive backlash. The entire question of equalization must be solved by individual preference, for there is much to be said on both sides and it is feasible to get good results either with or without equalizers. It is possible to prevent rattle in any case throughout the entire linkage by the careful installation of take-up springs that keep the linkage under tension at all times.

BRAKE-LININGS

The subject of this paper is brake design and not brake-lining. However, there are a few qualities of brake-lining that should be taken into consideration. In the first place, there is a direct connection between the two subjects, because good results cannot be expected from any brake-lining unless the brakes are designed so as to allow its good qualities to assert themselves. It is unfair to expect any brake-lining to give good results when the brake design is such that it is impossible for the heat generated in deceleration to be dissipated. It must be remembered that the coefficient of friction of brake-lining is different when the brakes are cool from what it is when they are hot. This has been demonstrated very effectively by the Bureau of Standards which, in cooperation with the Motor Transport Corps and the Society of Automotive Engineers, has made extensive tests of brake-lining materials. Many of these have been published. One interesting fact was demonstrated regarding the coefficient of friction. During the long-time runs with cooled drums, the coefficient remains more nearly constant than during hot tests. The average value of the coefficients of a number of samples of brake-linings was nearly 0.40. In some places it was as low as 0.30, while in a few samples only was the average over 0.50. The extreme values of the coefficients were approximately 0.28 and 0.60. The effect of leakage of oil to the brake-shoes was demonstrated in these tests by saturating samples of the lining with oil and then noting the coefficient of friction. A few samples saturated with oil and with oil constantly supplied showed a coefficient between 0.10 and 0.20. After discontinuing the supply of oil, the coefficient rose in from 15 to 30 min. to values between 0.20 and 0.30 and was then maintained steadily. The question of how much brake-area a car should have is one that has been given considerable attention since the tests mentioned were made. One very prominent manufacturer of brake-lining states that a car should have a brake with a surface equal to 1 sq. in. for every 17 lb. of car weight. This alludes to the actual surface of brake-lining that should be used.

Another fact that should be mentioned in this brief discussion of brake-lining is that it is very regrettable that the so-called standard figures on brake-lining are not really standard at all. One large manufacturer of brake-lining states that it is his belief that the number of sizes should be reduced materially. He says that four or five widths are ample to cover the range of passenger cars and, with the addition of one or two sizes, the same would hold true for trucks. This same manufacturer argues that the same thing applies to the thickness; it is the belief of this company that satisfactory and economical service cannot be obtained from lining less than 3/16 in. thick. To sum up these two points, the opinion of this company is that everybody would be benefited, from the manufacturer to the consumer, if the linings were standardized to eight numbers at the most. The dealer could then afford to stock the complete line and delays necessitated under the present diversified numbers would be lessened greatly. As a general matter, it can be stated that the prevailing view among brake-lining manufacturers is that the average passenger car and truck is under-braked and, consequently, that too severe stresses are being placed upon the lining and exaggerated requirements exacted. Looking at the matter from the other side of the picture, one prominent engineer in the passenger-car field states that he believes there is much room for improvement in brake-linings. Most of them are woven very loosely and are compressed easily, he says, "So that the brakes frequently must be taken up on account of the great pressure exerted on the brake-shoes compressing the woven asbestos, rather than because of actual wear that has taken place." The manufacture and composition of brake-lining should receive careful attention and treatment from the Society. They are certainly at least equal in importance to the design of the brakes themselves.

If we were to sum up the brake situation from what we have seen in the review of brake design up to this

point, we would be forced to the conclusion that we are obtaining as good results as can be expected with the brake systems now in use. If we are not getting these results, it is because we are neglecting some of the salient points that have been mentioned here. We have insufficient braking-area because the brake-drums are not large enough, the type of installation used does not apply the full surface at its full efficiency, we have weak or flimsy materials in the construction of the brakes, the layout is not such as to produce the best results, the brake linkages are incorrect and do not give the desired pressure on the brakes, or the heat-dissipating qualities are not sufficient to take care of braking for an extended length of time down long grades. When we have gone all through the features of design that make a brake good, we are in a position to ask ourselves whether we are obtaining the results that we should expect. A very large percentage of engineers will agree that we are not.

Brakes of the Future

We are entering a period in the economic life of the Country in which automotive transportation is just beginning to come into its own. With hundreds of millions of dollars to be expended for roads during the next few years, the possibilities of automobile transportation are just about to be realized. The through trunk-line roads to be constructed mean that automobiles will travel them from end to end at high rates of speed. We look for the time when speed-limits on these roads will be either abandoned altogether or lifted to such an extent that the express train will be rivaled.

If these conditions are to apply, it will be necessary to control the car much more effectively than is now necessary in the ordinary traffic, and we will have very little use for braking systems that are not superior to those that we now have installed. The time is coming rapidly when moderate rates of speed will prevail only it city driving, and throughout the Country the express lines for passenger or freight cars will be operated at speeds of from 30 to 50 instead of from 20 to 35 m.p.h. Many of our prominent national routes traverse many miles of actually mountainous country. The part of Lincoln Highway between Philadelphia and Pittsburgh, which has been much traveled during the past few years, was one of the big connecting-links for automobile transport during the war. Those who were in the motor transport service during the war will remember that it was necessary to reline practically every set of brakes on the trucks that reached the eastern coast after a trip over this highway.

The Engine as a Brake

It must be admitted frankly that the heat-dissipating qualities of our present braking-systems are not sufficient to care for the extreme load of mountain driving. To come through safely, we must use the engine as a brake. If this is acceptable and desirable, there is little more to be said; because, by using the engine as a brake, the braking system can be nursed carefully so that it will not be worn-out in an unduly short period of time. If, on the other hand, the procedure is unsatisfactory and we should have a braking system independent of the engine, we are driven to other methods. It should be stated that if automobile and truck designers expect the engine to be used as a brake, the elements receiving the braking stresses, such as the universal-joints and power-transmission parts in both the gearset and the rear axle, should be designed accordingly. It is necessary only to stand at the foot of the hill on the New Jersey side of the ferry from Dyckman Street, New York City, or at the foot of any of the long, steep hills around Pittsburgh, and listen to the squealing of dry and overheated clutch and transmission bearings to realize that there are many instances where the engine and transmission system is not adapted to taking the braking stresses.

Fig. 17—Hydraulically Operated Four-Wheel Brakes Employed on the Duesenberg Car

A development that is tending to make the use of the engine as a brake much easier is the invention of gear-shifting devices that permit changing speeds up or down regardless of the speed of the vehicle. It is the inability to slip from high gear into intermediate when going downhill that makes engine-braking very dangerous. With some of these new transmission-systems it is possible to go not only into intermediate but into low or even reverse should this be required under these circumstances.

Four-Wheel and Front-Wheel Brakes

The four-wheel brake offers some very interesting possibilities for both passenger cars and trucks. The chief criticism that has been directed against it is its complications. Whether this will be sufficient to kill the idea remains to be seen. I believe that within the next 5 years we will find a very marked increase in the use of this system of brakes. With a braking system in which all four wheels are equipped with brake-drums, the brakes being applied simultaneously by the service-brake pedal, and an emergency brake on the propeller-shaft, it would seem that a very efficient layout could be obtained. We are limited in braking ability by the frictional contact between the tires and the ground. There are four points of contact and, if all four wheels were locked, a

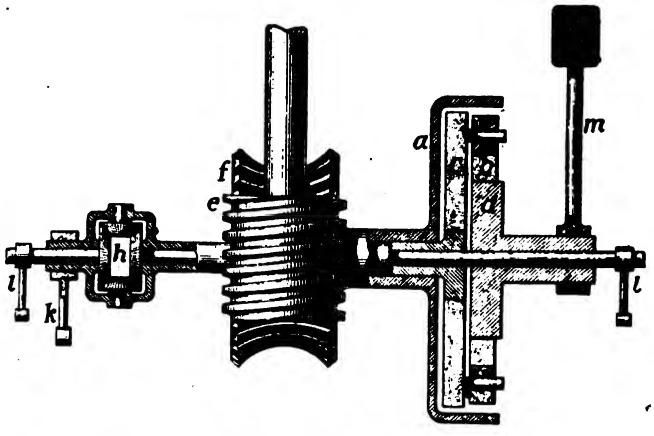


Fig. 18—Servo-Type Brake Used on the Hispano-Suiza Car

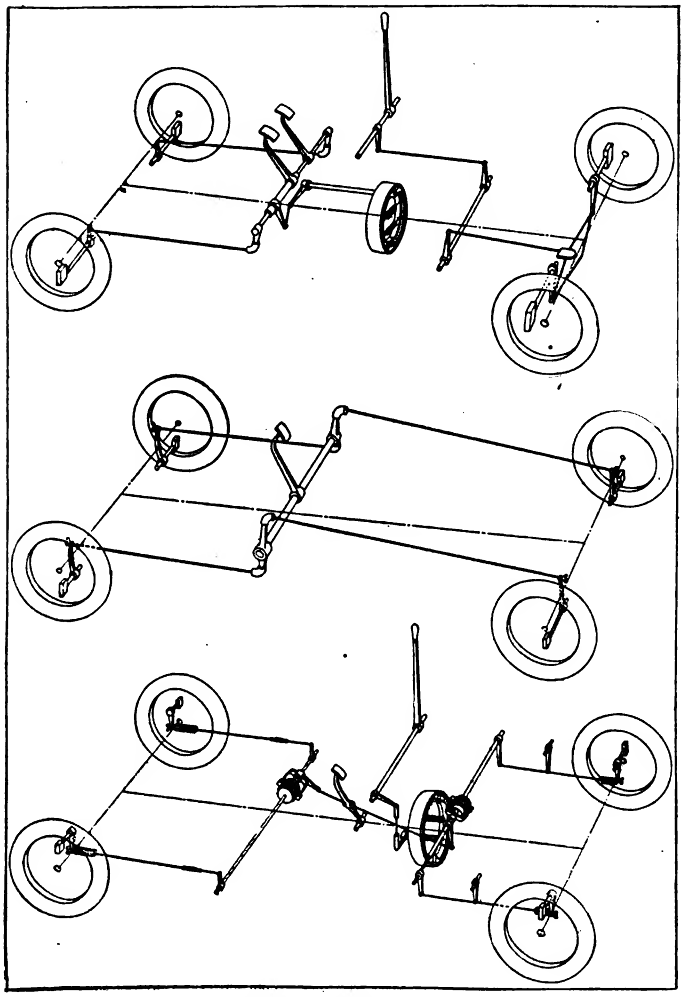


Fig. 19—Brake Connection Layout (Reading from the Top Down) on the Bellanger, Excelsior and Delage Cars

total braking drawbar-drag of a fixed quantity would be available to stop the car. This quantity is different for every condition of the ground but, inasmuch as the car weight can be stated as being approximately 60 per cent on the rear and 40 per cent on the front wheels, if we add the two front wheels to our braking equipment, we increase the braking possibilities by 40 per cent, neglecting the moment that tends to throw an increased weight on the front wheels and which would consequently augment the brake efficiency of the front-wheel brakes to a very large extent; or, to put it in another way, we reduce the amount of heat that must be dissipated through the rear drums by a like amount, in bringing the car to a stop. This reduction can be made in either the time or the temperature factor, provided we are bringing the car to a stop within a definite distance or in the shortest possible time.

There is no doubt about the increased efficiency of braking with four-wheel brakes. The tendency to skid is recognized to be less, and the question simmers down to whether the additional complication necessary is compensated by the increased braking-ability. It is a fact that the use of front-wheel brakes would tend to reduce the number of accidents due to skidding. They would be well justified even at a slight increase in the cost of manufacture and in spite of the added complication. With the present heavy traffic in all cities it is not unusual for 100 or more vehicles to suffer skidding accidents during the morning or evening rush hours. In the first light snowfall of 1921 in Detroit I counted 10 cars, during a single trip downtown, that had suffered rear-wheel fracture due to skidding over the slippery paved streets into the curbs. If front-wheel brakes would tend to cure this situation, as well as to increase the safety of both pedestrians and vehicles during wet and slippery weather, they should be carefully considered by the industry, which must hold itself responsible for all accidents due to imperfection of design. In hilly cities, such as Pittsburgh, the number of skidding accidents in wet weather is tremendous, in spite of the fact that cinders are spread on nearly all of the bad curves and grades to prevent these accidents. It is useless to say that operators should not drive at 20 to 35 m.p.h. down these wet and icy hills and then try to stop suddenly. If they do drive that way and are within the law, it is incumbent upon the industry to provide brakes that will meet the conditions if it is possible to do so.

It is possible to operate four-wheel brakes mechanically, hydraulically, pneumatically or electrically. All these methods have been tried with varying degrees of suc-

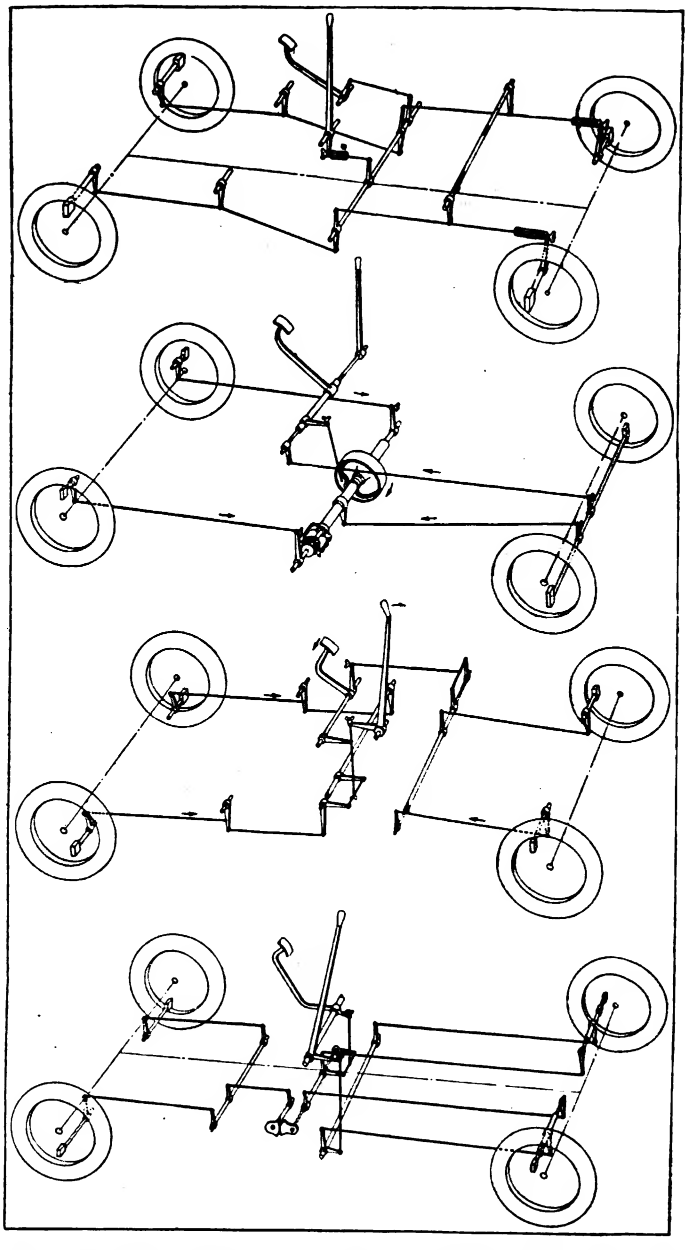


Fig. 20—Brake Connection Layout (Reading from the Top Down) on the Darracq, Hispano-Suiza, Isotta-Fraschini and Metallurgique Cars

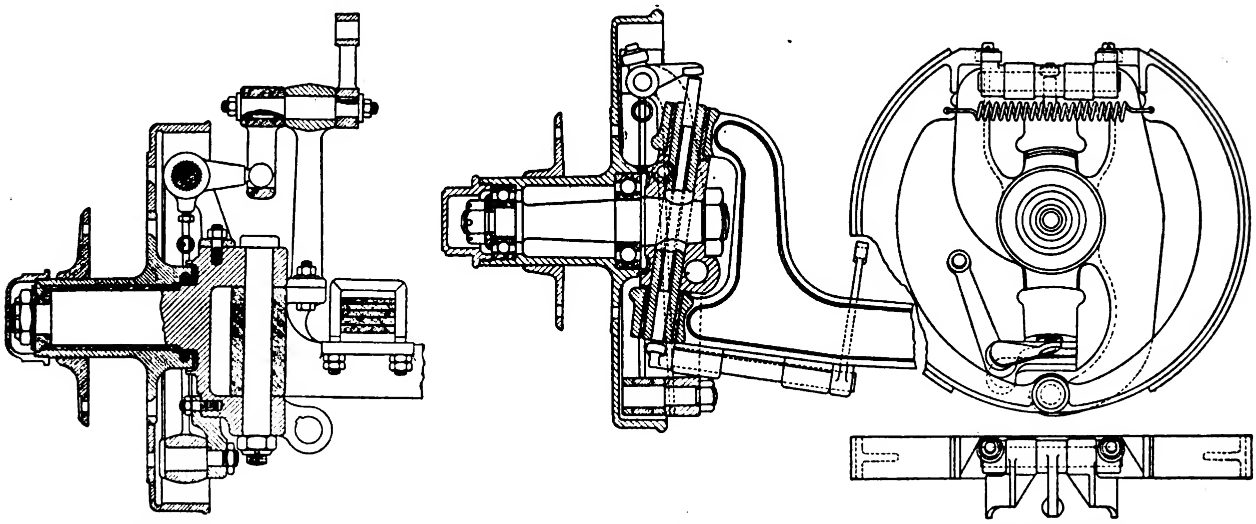


FIG. 21—FRONT-WHEEL BRAKE OF THE DUFOUR TRUCK AT THE LEFT AND AT THE RIGHT THE SCAT FRONT-WHEEL BRAKE OF 1910 SHOWING THE INCLINED STEERING PIVOT

cess. The hydraulic system probably shows the greatest promise at present because of its simplicity and also from the standpoint of perfect equalization. It has received one marked criticism in that failure of one of the pipes throws the entire system out of order. However, with a suitable large transmission-brake as emergency equipment, this objection is largely overcome.

A criticism of some weight that has been offered on front-wheel brakes is the tendency to go into a front-wheel skid; but it can be overcome. The front-wheel skid is caused by attempting to steer the car when the brakes are applied. It is apt to occur, for instance, in going into a curve at high speed and attempting to check the speed suddenly. The dragging action of the front wheels on the ground, enhanced by the angle at which the wheels are turning in steering, will throw the car into a front-wheel skid if the ground is at all slippery, or covered with a loose and non-adhering top-dressing. A remedy for this is to make the rear-wheel brakes slightly more powerful than the front-wheel brakes. On a recent installation of hydraulic four-wheel brakes on a heavy passenger-car, shown in Fig. 17, the brake-drums are forgings 16 in. in diameter on all four wheels. The drums are ground to obtain a perfect braking-surface. Circumferential fins are machined on the outer edges to provide strength, together with lightness and radiating surface. The four brakes are operated by hydraulic pressure. A master cylinder is connected to the brake-pedal and the liquid is forced through the lines running to the four wheels by a piston in the master cylinder. A small cylinder in each of the four brakes has a piston that is forced upward by the liquid entering the cylinder. The piston at the brakes operates a toggle-arm that, in turn, expands the two brake-shoes in each brake. All four of these brakes are operated simultaneously by the service-brake pedal. An interesting feature of the brakes is that, owing to the floating arrangement of the piston and the toggle, the brakes are self-centering and consequently self-equalizing. When the brakes are applied, they provide equal pressure against the drums. Water is used as the brake-operating fluid in summer, and an anti-freeze solution in winter. In this car the hand-brakes operate on a drum at the forward end of the propeller-shaft.

THE SERVO PRINCIPLE OF OPERATION

The Hispano-Suiza firm showed at the French Salon of 1919 a four-wheel-brake equipment that excited many

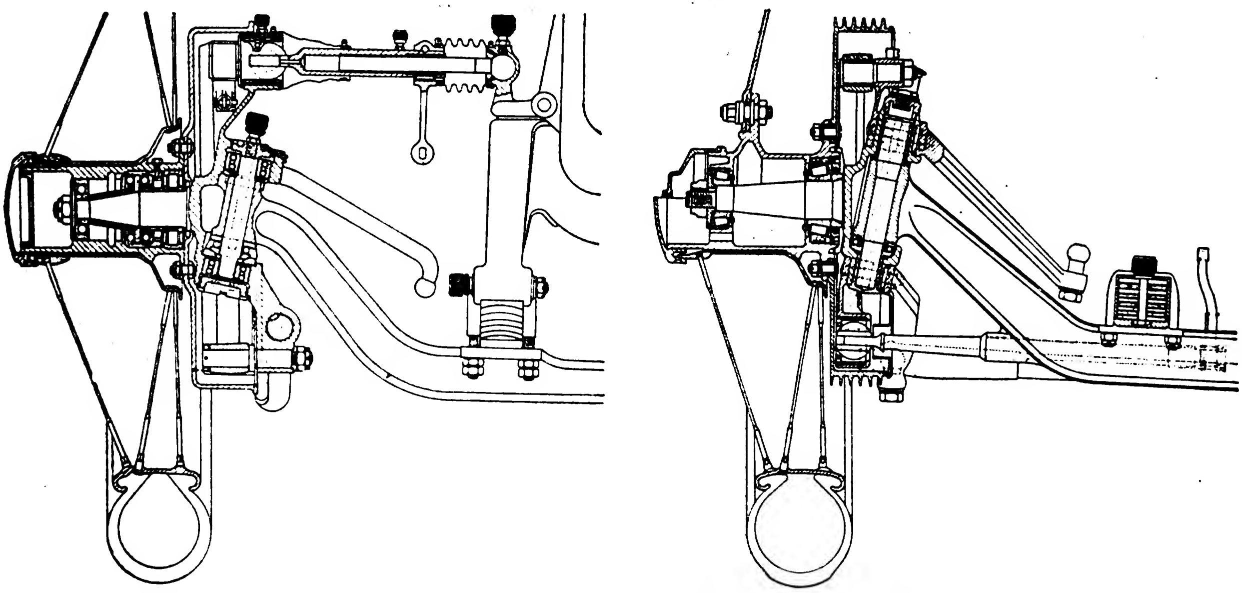


FIG. 22—AT THE LEFT THE DELAGE BRAKE WITH THE CAM ABOVE THE FRONT AXLE AND AT THE RIGHT THE METALLURGIQUE BRAKE WITH THE CAM BELOW THE AXLE

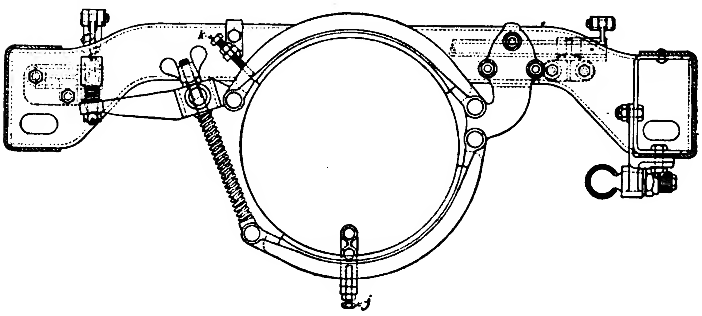


FIG. 23—TRANSMISSION BRAKE ON THE BENZ CAR HAVING A SIMPLE AND STURDY ADJUSTMENT OF THE OPERATING LEVERS

comments from European engineers. The Hispano-Suiza brake makes use of the servo principle, which is very closely related to the principle used in manipulating the steering-gear of large vessels. In the servo principle, the hand or foot operation simply sets in motion a more powerful mechanical means that registers exactly with the movement of hand or foot in manipulating the control. In steering a vessel of large size, turning the wheel sets in motion a steam engine or some other type of power that turns the heavy rudder an amount corresponding with the movement of the wheel. On the servo type of brake, the depression of the pedal causes a corresponding movement of the brake linkage by releasing some source of energy independent of the manual operation. On the Hispano-Suiza cars the energy which is made use of is the motion of the vehicle itself. Referring to Fig. 18, there is a drum, *a*, that turns with the movement of the vehicle. The segments *b* are mounted upon a transverse member, *c*, upon which are the pivot points for the segments *b*. The pedal that controls the brake is mounted upon an extension of the cam piece *d*. If the pedal *m* is turned through an arc of 1 deg., the cam piece *d* expands the segments *b*, causing them to make contact with the rotating drum *a*. Frictional contact causes the drum *a* to carry around with it in rotation the segments *b*, which, in turn, carry the transverse member *c*. But when the transverse member will have turned 1 deg., the segments also will have turned through 1 deg. and assumed their original relative position, and there is no further motion. During the time the brake-shaft rotates with the drum *a*, motion is being imparted to the braking mechanism by the worm *e* and wormwheel *f*. The wormwheel is solidly connected with the brake drum *a*. A differential, *h*, equalizes the tension of the front-wheel brakes; *k* is the lever controlling the rear brakes and *l* the lever controlling the front-wheel brakes.

[3] See *Omnia*, June, 1921, p. 30.
[4] See *Omnia*, October, 1921, p. 356.
[5] See *Automotive Industries*, Nov. 17, 1921, p. 964.

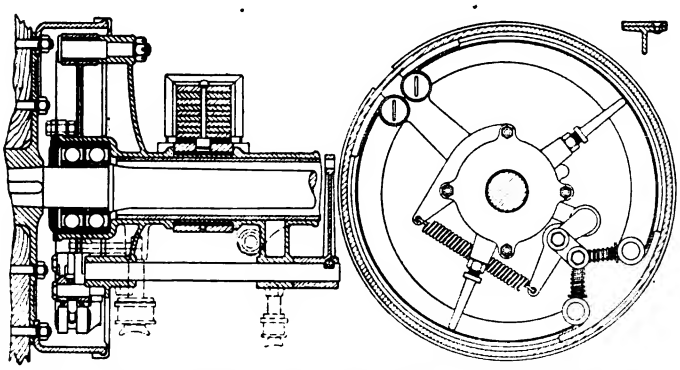


FIG. 24—REAR-WHEEL BRAKE EMPLOYED ON THE BENZ CAR

For information on experience with front-wheel brakes we must look to Europe, which has been a leader in this respect. Typical European layouts are reproduced in Figs. 19 to 22 inclusive. If we are to find effective brakes, naturally we should seek them in localities where they are absolutely required. Viewing cars that are operated in mountainous districts, such as the Alps, we find that their braking systems have been given very intensive study and that some interesting applications have been made; the front-wheel brake is the rule and not the exception on heavy cars. The servo arrangement is found here in principle, with two or three varieties of application. As a rule, however, the front-wheel brakes are operated by straight mechanical linkage.

MISCELLANEOUS BRAKING METHODS

We find all sorts of combinations of front and rear wheel and transmission brakes. Diagonal braking has been tried, putting the foot-brake on say a left-front and a right-rear wheel and the hand-brake on a right-front and a left-rear wheel. The Rochet-Schneider Co., after an exhaustive series of tests in the Alps, selected the front wheels and transmission for the foot-brake and the rear wheels for the hand-brake. On the Duesenberg car that distinguished itself in the French Grand Prix race, the foot-brake operates hydraulically all four wheels and the hand-brake is on the transmission. One important point in the installation of front-wheel brakes

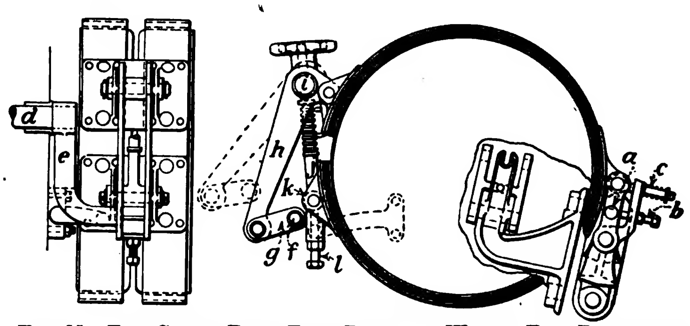


FIG. 25—THE CRANE BAND-TYPE BRAKE IN WHICH TWO RELATIVELY NARROW BANDS ARE EMPLOYED

is that the steering-knuckle pivot-pin must be inclined so that, if produced, it would intersect the point of contact of the center of the front tire with the ground. This is essential to preserve good steering-ability with front-wheel brakes. I shall not attempt to give a detail description of the various foreign brake-applications. A very complete article by H. Féron entitled, Les Freins sur Roues Avant (Front-Wheel Brakes),[3] appeared recently, and reference is made also to a very good description of the Delage front-wheel brake.[4]

There is an article on Automatic Brake Regulation to Prevent Wheel-Locking[5] in which is described a servo type of brake known as the Hallot that was exhibited on the Chenard-Walcker car at Paris. The brakes in this design consist of the usual drum, an expanding or contracting member, but instead of being rigidly keyed to the wheel hub, the drum is free to turn thereon. In addition to the above mentioned part, the brake comprises a disc or spider that is fastened upon the shaft, to be retarded to take the place of the web or spider of the ordinary brake-drum. The rim of this disc is formed with recesses in which centrifugal weights are located. These weights are pressed lightly against the inside of the brake-drum by coil-springs within them and, when the wheel is rotating, they are pressed against the drum by the additional force of the centrifugal action. Radial

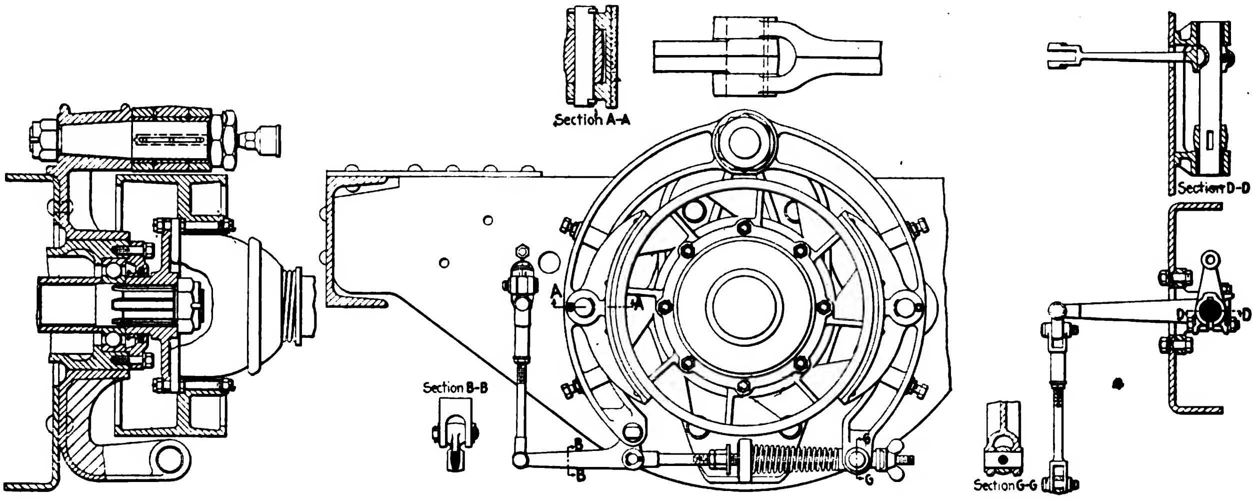


FIG. 26—CONTRACTING-SHOE TYPE BRAKE MOUNTED ON THE TRANSMISSION OF THE PACKARD TRUCKS AND OPERATED BY A HAND-LEVER

pressure, due to centrifugal force, varies as the square of the speed of the car and is, therefore, very great at high speeds and very small at low speeds. Suppose that the car is proceeding at high speed and that the brake is applied. At first, the brake-bands or sectors will slip on the drum, because the centrifugal weights rotating at very high speeds are applied with great force to the drum and hold it fast on the wheel hub. But, as the speed of the vehicle decreases, a point is reached where the friction between the brake-band and the drum exceeds that between the centrifugal weights and the drum, and slipping will occur between the latter parts. It will be seen readily that, with this construction, it is impossible to lock the wheels because, as the wheels approach a standstill, the centrifugal force of the weights becomes almost zero and the retarding efforts practically vanish. By proportioning the parts of the brake properly it is possible to limit the force of application to just a little less than that required to cause locking and then obtain the maximum retarding effect.

An interesting mechanically operated front-wheel brake was recently brought out by the Shuler Axle Mfg. Co. This is an internal expanding toggle-operated type and was recently described in one of the trade journals.[6]

The Benz car employs transmission and rear-wheel brakes, shown in Figs. 23 and 24. The transmission brake-drum is bolted together with the forward part of the universal-joint case. The brake-shoes of steel have cast-iron linings and their right ends are swiveled to a bracket bolted to the transverse frame-member. The other ends are operated by a lever and a bolt. When the linings become worn slightly, the shoes can be adjusted by a butterfly nut. After more extensive wear the brake-rod is shortened by screwing-up the yoke. In case of unequal distance of the brake-shoes from the drum, the lock-nuts *j* and *k* of the two screws are loosened and the screws adjusted accordingly. To prevent undue heating of the transmission brake, a water-tank is provided, at the right side of the transmission-case, from which cooling water is forced by exhaust-gas pressure to the sight-feed with a stopcock at the dashboard, whence it is allowed to flow to the brake-drum. The brake-shoes also have cooling ribs on the outside. A horizontal section

[6] See *Automotive Industries*, July 14, 1921, p. 79.

FIG. 27—EXPANDING-SHOE TYPE BRAKE USED ON THE PACKARD 3-TON TRUCK

through the drive-shaft and rear axle is shown in Fig. 23. Two parallel radius-rods serve to transmit the propulsive effort from the rear axle to the frame. They have an eye at the rear end supported by an axially drilled pin with provision for grease lubrication. The front end has a ball-joint spring-cushioned to damp-out road and starting shocks. This joint is lubricated with grease through a drilled pin. The rear wheels can be detached after removing the axle cap and nut by inserting a wheel-puller in place of the cap. The design of the rear-wheel brakes is clearly shown in Fig. 24. Inside the brake-drum are the two brake-shoes lined with asbestos fabric and carried on two pivots. The free ends are connected by toggles and a link with a lever-arm. Equalization of the two rear brakes is effected by means of the simple ball-headed balance-lever arrangement, shown in Fig. 24. When the brake-shoes are worn, adjustment can be made in the brake linkage, but it can also be made on the brake itself, after removing the rear wheel, by loosening the check-nuts and lengthening the toggles.

Henry M. Crane is among the advocates of the band-type brake, provided it is properly constructed. A design incorporating the desirable features of this brake, prepared by Mr. Crane, is shown in Fig. 25. As has been pointed out, one of the chief advantages of the band brake is the fact that it can be made to bear on almost the full circumference of the brake-drum, which is 12 in. in diameter, whereas in the internal shoe-type brake it is difficult to secure an effective contact over more than one-half the circumference. The expanding-shoe type also tends to distort the drum, while there is no such tendency in the band type. The large arc of contact and other features make it possible to make a band brake of given capacity much lighter than one of the internal-shoe type. Smoothness in brake operation depends to a considerable extent upon low unit-pressure on the braking surface. With the band type a low uniform pressure is readily secured in combination with a brake of adequate capacity and moderate weight. Smooth operation is facilitated by providing a rigid brake anchorage.

Referring to the illustration of the Crane design of band-brake, it will be noted that two narrow drums, placed back to back, are employed, and that two relatively narrow bands, 2 in. in width, are used in place of a single wide band. The two primary reasons for using this dual construction are that two narrow drums are less apt to distort due to heating than a single wide drum, and two narrow bands are less likely to bear unevenly than a single wide band. Uneven bearing on a wide band may tend to cause chattering. By placing the brake-drums back-to-back with spacers between, and drilling holes in the web of the drum, air is drawn through the space between the drums to assist in cooling them.

A single rigid anchorage is provided. The link *a*, attached to the anchorage at one end and to the band at the other, is held against the stop-screw *b* by the spring *c*. The spring keeps the band lining out of contact with the drum at all times when the brake is in the off-position. Two views of the linkage employed for operating the brake are shown. The operating shaft *d* carries a heavy bent arm *e*, the outer end of which engages the hole *f* in the link *g*. The other end of the link *g* is pinned to the long arm of the lever *h*. This lever is pivoted on the pin *i*, to which is attached the adjustable link *j*. The lower end of the link *j* is pivoted in a fitting *k* riveted to one end of the brake-band. The other end of the brake-band is connected to the short arm of lever *h*. A spring surrounding the link *j* holds the two ends of the band apart. The fitting *k* rests against the adjustable stop-screw *l* in its off-position. Motion of the long arm of the lever *h* away from the drum causes the two ends of the brake-band to come more closely together and brings the braking surface into engagement with the drum.

The brake-band is rolled to a true circle; consequently, the brake cannot drag if the stops *b* and *l* are properly adjusted. It will be noted that the link *g* remains in a substantially radial position in all positions of lever *h*. This counteracts any tendency there may be for the brake to jamb or become self-acting due to the tendency of the braking friction to carry the band around. It will be noted that the difference in the length of the arms of lever *h* is sufficient to give considerable multiplication of the pull applied to the long arm. This makes unnecessary any other multiplication of the pressure than that provided by the normal difference in the length of the two arms of the operating pedal. The brake-band is, of course, stiff enough to clear at all points, but it is sufficiently flexible to insure uniform contact-pressure over the entire braking surface, and thus distribute wear.

This brake is designed for application to the transmission. Light pedal-pressure is sufficient to lock the wheels of a heavy car easily even when there is oil on the braking surface. The use of a small quantity of oil on the brake is, in fact, recommended as a means of facilitating smooth operation and minimizing wear.

The Westinghouse Air Brake Co. has made a number of interesting installations that have been applied to several hundred trucks and cars with, it is claimed, very satisfactory results. In this system the engine is used to furnish the pressure for operating the brakes, making it unnecessary to install an additional compressor. Pressure is imparted to the brake connections by diaphragms. The compressed air, or gas, is supplied through a special ball check-valve, of dimensions not greatly exceeding those of a spark-plug. This check-valve is known as the accumulator, and is screwed into the cylinder-head generally in place of an existing pet-cock. From the accumulator the air is led by a copper-tubing connection to a sheet-steel reservoir. When the engine is started, each explosion in the cylinder sends a puff of gas into the reservoir and, by the time the machine is put in motion, enough pressure has accumulated in the reservoir to permit proper braking of the vehicle at low speeds. It is claimed that by the time the vehicle has traveled a distance equal to that of a city block, enough pressure has been accumulated in the reservoir to make possible several high-pressure brake applications, even if the engine were no longer keeping up the pressure. If no brake applications are made after the reservoir has reached full pressure, the engine ceases discharging gas into the reservoir because the back-pressure from the reservoir seats the ball check-valve in the accumulator, and prevents further egress of the gas from the cylinders. When the pressure in the reservoir drops, due to application of the brakes, the ball-check in the accumulator functions again, and the pressure in the reservoir is brought back to the high point after traveling a short distance.

From the reservoir a connection is made to a brake valve located in a convenient position on the steering-column or dashboard. The brake valve has a handle comparable with the spark or gas-control lever, and moving through about the same arc. The brake valve is designed so that in admitting air from the reservoir to the chambers that directly apply the brakes, a certain

pressure will be established in the brake chambers corresponding to the position of the brake-valve handle, irrespective of any excess pressure that may exist in the reservoir. The farther the brake-valve handle is moved from its off-position, the greater the pressure in the brake chamber is, up to the point corresponding to the emergency-application position of the brake-valve handle. The brake chamber consists of two dished plates between which is a heavy rubber diaphragm. The air is admitted on one side of the rubber diaphragm and causes it to move forward. On the other side of the diaphragm is a plate into which is fastened the push-rod that is connected to the brake-rod. In order that the brakes can be released more quickly than would be the case if all the air from the brake chambers were caused to exhaust through the exhaust port in the brake valve, a quick-release valve is installed in close proximity to the brake chambers. One of the interesting features of this system is that it can be used in connection with trailers, making it possible to brake the trailers as well as the tractor. In case of accidental disconnection between the trailer and the tractor, the brakes are applied automatically by a special emergency-valve.

Truck Brakes

On truck brakes, the following statements have been made by an engineer specializing in this work and seem to represent what is considered good practice.

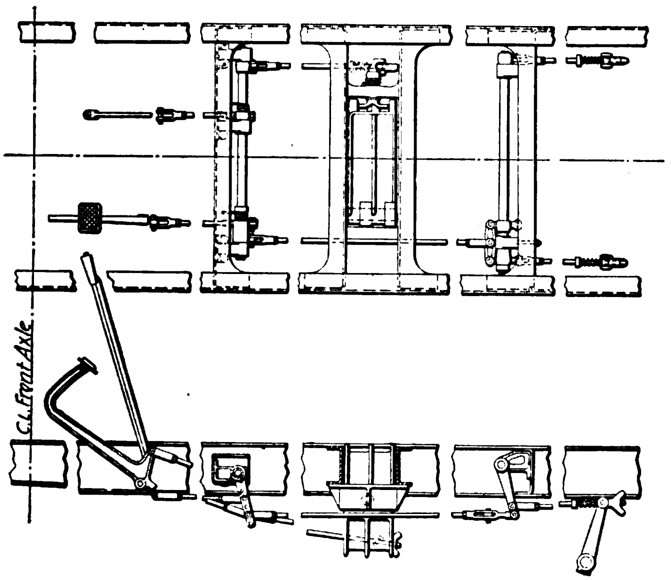


Fig. 28—Brake-Rod Arrangement Employed on the Mack Truck, the Foot-Brake Being on the Rear Wheels and the Hand-Brake on the Transmission

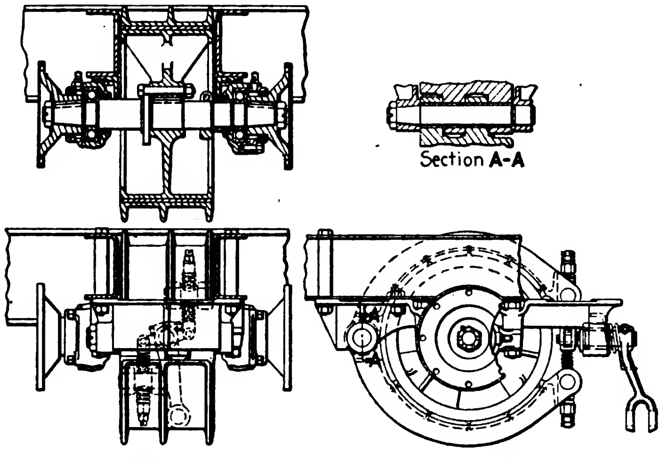


Fig. 29—Contracting-Shoe Type Brake Used on the Transmission of the Mack Truck

(1) Truck brakes should be designed in terms of truck weight in pounds per square inch of lining. This has, of course, a distinct bearing upon the durability of linings. It is a very much neglected factor in some designs. A weight of from 30 to 50 lb. per sq. in. of lining for a hand-brake on the rear wheels gives satisfactory results. For a foot-brake applied to the transmission, a greater value can be used, namely, 100 to 150 lb. per sq. in. In both cases a smaller value is much to be preferred; in fact, the lower this can be kept the better

(2) The average brake-lining will give the best results provided the pressure does not exceed 100 lb. per sq. in.; as in item (1), the lower the pressure is, the better the results become

(3) Calculations should be made for leverage on a value of about 26 to 1 for the transmission brake; 50 to 1 for the hand-brake on the rear wheels; and 20 to 1 for the foot-brake on the rear or the front wheels; these values have been found through experience to be very satisfactory

(4) The average man can exert a pressure of approximately 200 lb. on a pedal and about a 100-lb. pull on a lever. It should be remembered that 75-per cent efficiency for linkage is a high figure in view of the fact that the joints invariably lack lubricant and therefore stick

(5) Other important values are 0.25 for the coefficient of friction of fabric and 0.50 for the coefficient of friction of the tire on the road

Some representative examples of the brakes used on different American trucks are shown in Figs. 26 to 29 inclusive.

CROSS-COUNTRY FLYING BY THE AIR SERVICE

It is estimated that during the calendar year 1921 a total of 5,063,909 man-miles were flown by the Air Service personnel on cross-country flights. These figures cover only flights exceeding a distance of 10 miles from an airdrome with a definite destination in view, either with the purpose of landing at that destination or returning from the destination upon completion of the specific purpose of the flight without landing away from the airdrome.

By man-miles is meant the number of miles flown by each man in any one plane; a plane carrying two people and traveling to a station 50 miles distant and return will carry out 200 man-miles of cross-country flight. A tabulation of the number of man-miles flown at the various Air Service stations shows that Post Field, Fort Sill, Okla., heads the list with 826,084 man-miles. The commanding officer of that station states that the total time flown by all pilots at the field, 9,836 hr. at 85 m.p.h., totals 836,060 miles or, based on two persons in each ship on each flight, the man-miles total 1,672,120, approximating a distance equal to 67 times around the world. Mather Field, Mills, Cal., is second with 807,119 man-miles including forestry patrol flights, and Vancouver Barracks, Wash., is at the foot of the list with only 225 man-miles. The flights from McCook Field, Dayton, Ohio, the headquarters of the engineering division of the Air Service, totaled 290,940 man-miles, this field ranking sixth.—Air Service News Letter.

SUGGESTED PROBLEMS FOR RESEARCH

THIS is the first of a series of articles in which the Research Department proposes to discuss some of the research possibilities of various problems that seem to be of interest or importance at this time. For instance, the problem suggested below is of special academic interest and might be undertaken to advantage by one of the university laboratories where instruction and experience are as important as research results. The present status of the problem will be outlined, the phases that will readily lend themselves to laboratory research will be stressed, and a short bibliography included of the more important papers on the subject. It is suggested that the Research Department be kept informed of research work undertaken on any phase of a problem, so that duplication of effort may be avoided.

Possible Effects of Water Injection on Engine Power and Economy

Of the comparatively scant material that has been published on the subject of water injection, the references given in this article represent, it is believed, the most worthwhile studies of the problem that have appeared in recent literature. They all deal, however, except for a brief mention by J. E. Schipper, with the effect of the introduction of water as such and not with the effect of humidity, i. e., water occurring as vapor in the intake air.

The problem is a rather complex one, involving some important thermodynamic considerations, and should be taken up from both the theoretical and experimental sides, preferably by the same personnel. The reasons for undertaking this problem appear to be as follows:

(1) It has some practical importance, particularly in connection with the use of kerosene in tractors

(2) It constitutes an important but neglected phase of the problem of detonation

(3) It is the one variable of possible importance that has been universally overlooked in nearly all precision studies of engine performance

(4) The problem is one that would afford the best of training and experience to graduate students, not to mention the instructor, if it were taken up in a school laboratory

(5) It should require no appreciable outlay of money, as it should be handled in educational laboratories where nearly or quite all the necessary apparatus is at hand and where the staff is available

The injection of cold water into the intake system or the engine cylinder may have the purposes of (*a*) producing steam by its evaporation, thus developing power; (*b*) cooling the cylinder and doing away with the need of jacketing and (*c*) reducing the compression temperature; the first two of which do not seem to be of much practical interest.

In general the development of power by the evaporation of the injected water is based on an unsound theory. Heat taken from the products of combustion before or during expansion, to vaporize water and superheat the steam, represents a direct loss of efficiency. There is, however, a practical compensation for this loss in that the reduction of temperature of the charge reduces the loss to the jackets. While the possible gain seems not to equal the loss, this question needs careful analysis.

Under a special condition as carried out by Hopkinson, a gain of efficiency is possible when water is injected into the cylinder after firing, the condition being that the water receives most of its heat from the heated cylinder-walls and not from the gas charge. In this way some use is made of heat that otherwise would be wasted. The method seems to have little importance theoretically and none practically, unless it be for large stationary plants. It is not worth investigating as an automotive problem.

The injection of water as a spray into the intake charge was utilized by Banki to permit higher compression-ratios by lowering the compression temperature. Used in this way water has a two-fold effect:

(1) Whatever heat is absorbed in vaporizing the water before the end of the compression stroke represents a gain in efficiency by reducing negative work and perhaps also by lowering the absolute temperature. There appears also to be a gain in efficiency through a reduction in the loss to the cylinder-walls because of lower combustion-temperature, but a loss due to the increased specific heat of the charge

(2) If use is made of the lowered compression-temperature, the compression-ratio can be raised and increased economy secured in this way; in other words, water can be used as an anti-knock material and its properties as such should be carefully studied

Another effect that seems to have been overlooked until recently is that of water vapor or humidity on the vaporization of fuel in the manifold. With dry air, the complete vaporization of the fuel charge lowers the air temperature about 40 deg. fahr. If the moisture-content is such that the air becomes saturated with water before this lower temperature is reached, the heat liberated in the condensation of water will tend to prevent this drop in temperature and to increase the vaporization of the gasoline. This action can modify considerably the performance of an engine, particularly when using such volatile fuels as aviation gasoline.

The foregoing is not an attempt to analyze completely the problem of the effect of water on engine performance, but only to point out certain phases of the problem that are in need of solution, both to add to our knowledge of the fundamentals of gasoline-engine performance and to afford data that may be of much practical value.

References

Water Injection May Increase Power. J. E. Schipper. *Automotive Industries*, Nov. 15, 1917, page 868.

Results are given of tests on a 4 x 5½-in. truck engine running on kerosene where water in the form of a cold spray increased the indicated mean effective pressure from 137 to 145 lb. per sq. in. The water removed preignition knock and, the author claims, "softened" the explosion by making the card "fatter" after the initial part of the stroke. The theories presented are that water quenches the incandescent points of carbon, and that it absorbs considerable heat due to its latent heat of evaporation.

Why Water Injection May Cause an Increase of Power. P. M Heldt. *Automotive Industries*, Dec. 20, 1917, page 1081.

The author discusses the Banki engine, in which water was used to permit higher compression-ratios and higher economy. The use of kerosene, with its greater tendency to detonate and preignite, emphasizes the advantages to be gained by the use of water. The relative heat-losses from the cylinder gases at different parts of the stroke are discussed at some length and it is shown that, if the presence of water reduces the maximum explosion-temperature and increases the temperature later in the stroke, even though there is a considerable net loss of heat to the water, the reduction in loss to the cylinder-walls may result in a net gain in efficiency. As regards decarbonizing effect, the author questions whether this is not entirely an illusion. The reduction of knock may eliminate the main effects of carbon deposits without affecting the amount of deposit.

Influence of Water Injection on Engine Performance. V. W. Brinkerhoff. National Advisory Committee for Aeronautics, Report No. 45, page 521.

The author reports a series of practical overall tests with two different engines to determine the direct effect on power and economy of cold water admitted into the intake-manifold in the form of a spray. The conclusion is drawn that

no measurable increase in power or economy is produced with any percentage of water and that beyond a certain amount the effect is detrimental.

Water Injection in Gas and Oil Engines. *Automobile Engineer* (London), December, 1920, page 492.

This article is a general discussion of the various effects of water injection, to answer the question whether the reasons for its abandonment in recent practice are sufficient. The main points covered are much the same as those discussed at the beginning of this article.

MARCH COUNCIL MEETING

THE meeting of the Council held on March 7 at the Engineers' Club, Dayton, Ohio, was attended by President Bachman, Past-President Beecroft, First Vice-President Whitbeck, Second Vice-Presidents Clark, Watts and Young, and Councilors Brush, Crane, Smith and Strickland.

One hundred one applications for individual membership and 32 for student enrollment were approved. The following transfers in grade of membership were made: From Member to Service Member, F. E. Richardson and J. V. Costello; Member to Foreign Member, E. Gassmann; Associate to Member, C. C. Bowman; Junior to Associate, F. Klein; Junior to Service Member, C. F. Taylor.

The financial statement showed as of Feb. 28 a net balance of assets over liabilities of the Society of $128,485.31, this being $5,307.50 less than the corresponding figure on the same day of 1921. The income of the Society for the first 5 months of the current fiscal year amounted to $64,562.68. The operating expense during the same period was $74,646.36. The expense accounts showed a net saving of $6,398.22 in comparison with the same period of the last fiscal year, taking into consideration the expense to date of the newly established Research Department.

The Council revised the list of prices for publications of the Society. The new schedule is printed elsewhere in this issue of THE JOURNAL.

Considerable discussion was had of subjects of papers for presentation at the coming Summer Meeting of the Society.

The following additional subject was assigned to the Standards Committee:

Wire Wheel Spokes—Axle and Wheels Division, with Iron and Steel Division cooperating.

The following appointments to the Standards Committee were made, these being in addition to those listed in the February issue of THE JOURNAL:

AERONAUTIC DIVISION

Edward Wallace	Glenn L. Martin Co.

AGRICULTURAL POWER EQUIPMENT DIVISION

D. P. Davies	J. I. Case Threshing Machine Co.
C. E. Frudden	Hart-Parr Co.
O. W. Young	Hyatt Roller Bearing Co.

ROLLER BEARING SUBDIVISION

H. I. Beard	Ball & Roller Bearing Co.

CHAIN DIVISION

F. C. Thompson	Morse Chain Co.

ELECTRIC VEHICLE DIVISION

Charles R. Skinner, Jr.	New York Edison Co.

ENGINE DIVISION

William Turnbull	Holt Mfg. Co.
E. J. Hall	Hall-Scott Motor Co.

FRAMES DIVISION

D. G. Roos	Locomobile Co. of America
C. W. Wright	A. O. Smith Corporation

IRON AND STEEL DIVISION

W. H. Phillips	R. D. Nuttall Co.
S. P. Rockwell	Consulting Metallurgist

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

Don D. Myers	Auto-Lite Corporation
H. L. Zabriskie	Diehl Mfg. Co.

LUBRICANTS DIVISION

G. A. Green	Fifth Avenue Coach Co.

NOMENCLATURE DIVISION

J. B. Bartholomew	Avery Co.
Jos. VanBlerck	Jos. VanBlerck, Inc.

PASSENGER CAR DIVISION

Howard Marmon	Nordyke & Marmon Co.

RADIATOR DIVISION

A. L. Swank	Long Mfg. Co.
Fred M. Young	Perfex Radiator Co.

TRANSMISSION DIVISION

E. E. Wemp	Long Mfg. Co.

The action taken by the Council in connection with future distribution of the TRANSACTIONS, as well as the Membership Roster of the Society, is set forth on page 261 of this issue of THE JOURNAL.

Announcement was made of the appointment by President Bachman of the following to serve as members of the Highways Committee of the Society, under the chairmanship of H. W. Alden:

W. A. Brush	W. E. Lay
G. A. Green	F. A. Whitten

H. H. Brautigam was elected second vice-president for marine engineering, H. E. Morton, who was regularly nominated and elected by the voting members of the Society to serve in this capacity, having resigned.

It was decided tentatively that the next meeting of the Council should be held in Indianapolis on May 8.

EFFECT OF PHOSPHORUS AND SULPHUR IN STEEL

THE Joint Committee on the Investigation of the Effect of Phosphorus and Sulphur in Steel, which is composed of representatives of a number of the leading technical societies including the American Society for Testing Materials, the American Society of Mechanical Engineers and the Society of Automotive Engineers, has issued a progress report. Copies of this report, which covers the activities of the Committee for the past 2 years, can be obtained from C. L. Warwick, its chairman, 1315 Spruce Street, Philadelphia, or from the Bureau of Standards, City of Washington. It is expected that all of this material will be published ultimately by the Bureau of Standards.

Tentative Schedule of Division Meetings

Tentative Meeting Schedule

Division	Chicago	Cleveland	Detroit	New York City	Philadelphia
Aeronautic				May 10	
Agricultural Power Equipment	April 18[a] April 19 May 13				
Axle and Wheels		May 2[b]			April 7[c]
Ball and Roller Bearings				May 1	
Electrical Equipment			April 14		
Electric Vehicle			May 10	April 5	
Engine	April 17 April 18[a] May 11				
Iron and Steel			April 11		
Isolated Electric Lighting Plant	April 18[a]				
Lighting		May 3			
Lubricants (Joint meeting with Agricultural Power Equipment, Engine, Isolated Electric Lighting Plant, Motorcycle and Stationary Engine)	April 18				
Motorboat				April 10	
Motorcycle	April 18[a]				
Nomenclature				April 3	
Non-Ferrous Metals		May 1			
Parts and Fittings			April 12		
Passenger Car		May 2[b]			
Passenger-Car Body			May 8		
Screw Threads		May 1			
Springs			May 5		
Stationary Engine	April 18[a] April 19 May 12				
Storage Battery				May 5	
Transmission			April 13		
Truck			May 9		

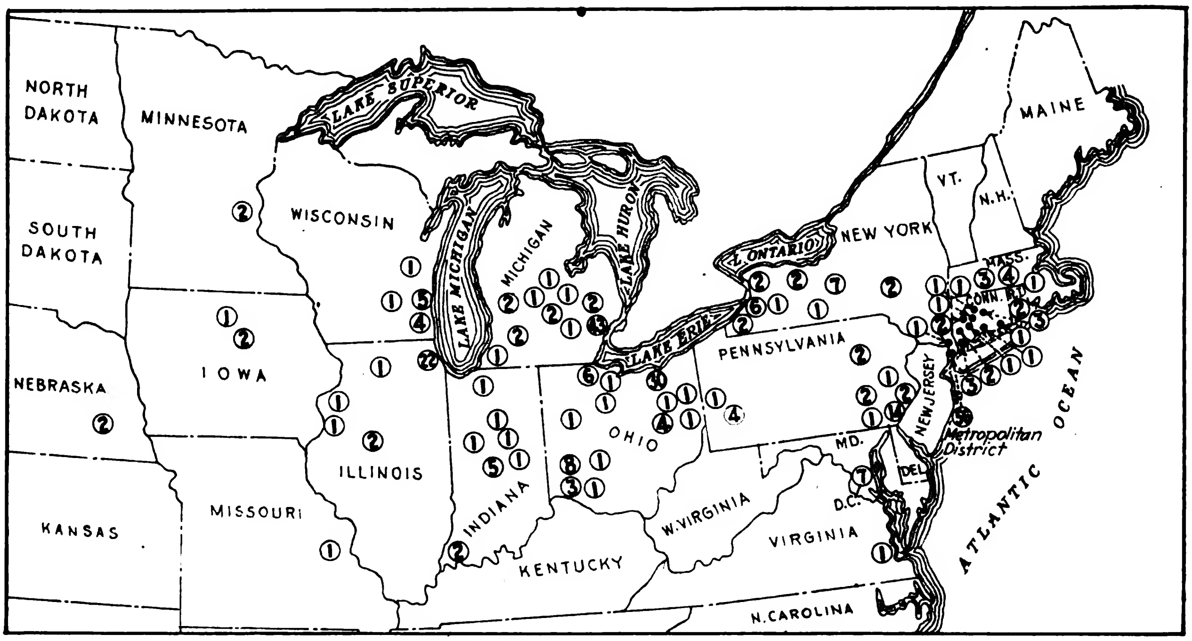
[a] Joint meeting with Lubricants Division.
[b] Joint meeting.
[c] Passenger-Car Hubs Subdivision only.

THE planning of the meetings of the several Divisions of the Standards Committee for the period between the beginning of this administrative year and the Summer Meeting of the Society in June has been completed so far as possible at this time. Two series of Division meetings have been arranged as shown in the accompanying tentative schedules, which will be followed as nearly as may be. It is probable that some changes will be made in them due to conditions that are sure to arise but cannot be foreseen at this time. It is important that the members of all Divisions of the Standards Committee, particularly of those scheduled for meetings, bear in mind in forming their plans that notice of the matters to be taken up, as well as of the definite time and place of their Division meetings, will be sent to them from the Standards Department 10 days or 2 weeks before the meetings.

The schedules were determined by several factors, including the number of subjects under consideration by each Division, their present status and the probable length of time that will be required to reach the point where consideration of them in Division meeting will be necessary. Meetings are planned for only those Divisions from which definite reports at the Standards Committee and Society meetings in June can be expected on the basis of the prospective progress in the work up to the time of the respective Division meetings. The actual progress in this connection will depend mostly upon early action by Subdivisions that are working on the various subjects and upon the promptness with which replies are received to questionnaires and circular letters that have been sent out to the industries by the Standards Department of the Society. In many instances final Division action can be secured by correspondence between the Standards Department and the Division members. This enables the Divisions to devote practically their entire time in meetings to consideration of the more important or difficult subjects.

The Standards Committee membership this year is approximately 20 per cent greater in number than any previous year, due largely to the rapidly increasing interest in engineering standardization and fuller appreciation of its value. Although the automotive industries have been passing through a period of depression, their recovery has commenced and there are indications that this recovery will be economically sound and possibly more rapid than in many other general industries. This naturally has led the Society to secure a broader representation on its Standards Committee for this year and to seek closer cooperation with other organizations of national scope by direct representation on a number of the Divisions.

An analysis was made of the geographical distribution of the Standards Committee members as one of the determining factors in deciding upon the places of meetings, to balance as nearly as possible the necessary amount of traveling required of each member. The more than 300 Committee members reside in 78 different cities, practically all of them in the Northern Central and Atlantic States. The most central locations for Division meetings are New York City, Philadelphia, Cleveland, Detroit and Chicago. The schedules therefore provide for sessions at these points at



DISTRIBUTION OF THE MEMBERS OF THE VARIOUS STANDARDS COMMITTEE DIVISIONS

State	City	Number of Members
Connecticut	Bridgeport	3
	Bristol	1
	Danbury	2
	Groton	1
	Hartford	3
	Middletown	1
	New Britain	1
	New Haven	1
	Waterbury	2
District of Columbia	Washington	7
Illinois	Chicago	22
	Moline	1
	Peoria	2
	Rockford	1
	Rock Island	1
Indiana	Anderson	1
	Evansville	2
	Indianapolis	5
	Lafayette	1
	LaPorte	1
	Muncie	1
	Wabash	1
Iowa	Charles City	1
	Waterloo	2
Massachusetts	Chicopee Falls	1
	Springfield	3
	Watertown	1
	Worcester	4
Michigan	Alma	1
	Buchanan	1
	Detroit	43
	Flint	2
	Grand Rapids	2
	Kalamazoo	2
	Lansing	2
	Marysville	1
	Pontiac	1
	Saginaw	1
Minnesota	Minneapolis	2
Missouri	St. Louis	1
Nebraska	Lincoln	2
New York	Buffalo	6
	Depew	1
	Ithaca	1
	Jamestown	2
	Lockport	2
	New York City (Metropolitan District)	56
	Portchester	2
	Rochester	2
	Schenectady	2
	Syracuse	7
Ohio	Canton	4
	Carthage	1
	Cincinnati	3
	Cleveland	30
	Clyde	1
	Dayton	8
	Lima	1
	Port Clinton	1
	Salem	1
	Springfield	1
	Toledo	6
	Warren	1
	Youngstown	1
Pennsylvania	Bethlehem	2
	Coraopolis	1
	Lancaster	1
	Philadelphia	14
	Pittsburgh	4
	Pottstown	1
	Reading	2
	Wilkes-Barre	2
Rhode Island	Providence	2
Virginia	Hampton	1
Wisconsin	Milwaukee	5
	New Holstein	1
	Racine	4
	Waukesha	1

the best times that could be selected for continuity in the series of meetings.

Aeronautic Division

Although there is a long list of subjects before this Division, most of the work contemplated applies to powerplants. It is expected that the Powerplant Subdivision will have several reports ready for Division action at its meeting in New York City on May 10.

Agricultural Power Equipment Division

Probably the most important work of this Division will be in cooperation with the Lubricants Division at the meeting in Chicago on April 18 to consider standard specifications for lubricating oils that have been generally circularized. It is hoped that the Subdivisions which are working on Tractor Belts and Pulleys, Tractor Testing Forms and Tractor Plowing Speeds will report to the Division at its meeting in Chicago on April 19, and that action can be taken with regard to Tractor and Implement Drawbar Connections. The meeting in Chicago on May 13 is planned to complete the Division's work prior to the Summer Meeting of the Society in June.

Axle and Wheels Division

A Subdivision has been working on the subject of Brake-Drums on which a report is anticipated at the Division meeting in Cleveland on May 2. The principal work before this Division is the preparation of a recommendation on Front-Axle Hubs for passenger cars. A Subdivision is now making a study in this connection. As the Passenger Car Division also is directly interested in the subject, a joint meeting of the Divisions has been scheduled. It is possible that the Subdivision on Differential Gears will report at this meeting.

Ball and Roller Bearings Division

There are a number of subjects before this Division upon which reports are expected for consideration at the meeting planned to be held in New York City on May 1. A new Subdivision was appointed last January to continue the work of making several revisions of the present standard for Metric Roller Bearings to make it more complete and uptodate with regard to sizes, tolerances, cage clearances, corner radii and other details.

In connection with the ball-bearing standards, the subjects to be acted upon include possible changes in the widths of the wide-type bearings, extending the number of sizes and making other changes in the several series of the annular type, largely in an endeavor to come to agreement with foreign manufacturers and thus establish more nearly similar standards internationally. Also, the advisability of establishing an American standard Extra Light Series will be considered.

A Subdivision is preparing a report on Metric Thrust Ball-Bearings and it is hoped that its deliberations will be completed in time for final study at the Division meeting.

Electrical Equipment Division

Subdivision reports on Breaker Contacts and Small Magneto Mountings have been submitted generally in a canvass upon the results of which the Division will act. Among the subjects with relation to which definite recommendations are expected are Generator Strap-Mountings, Generator Through-Drive Shafts and, possibly, Magnet Wire Specifications. Revisions that will improve the present standards for Generator Flange-Mountings, Starting-Motor Flange-Mountings and Ignition Distributor Mountings are expected. The Division should also consider revision of the present standards for cable and wire terminals. It is planned to hold a meeting of the Division in Detroit on April 14.

Electric Vehicle Division

Although no electric-vehicle standards have been adopted by the Society for some time, it is the intention to undertake the standardization of storage-battery cradle and tray dimensions and to standardize on one size of battery charging-plug. A meeting will be held in New York City on April 5 to start this work and it is hoped that some concrete recommendations will be ready for final discussion at the meeting planned to be held in Detroit on May 10.

Engine Division

At the April 17 meeting in Chicago it is planned to have at hand the Subdivision report on Carbureter Flanges for motorcycles and to prepare a revised recommendation for Engine Testing Forms along lines suggested at the January meeting of the Society in New York City. Two new subjects, Engine Support Arms for subframe construction and Crankcase Drain-Plugs, await Division action. It is expected that final recommendations on some of these subjects can be made at the May 11 meeting in Chicago.

On April 18, the Engine Division will meet jointly with the Lubricants Division and the other automotive Divisions listed in the schedule, to act upon the Lubricating Oil Specifications prepared by the Lubricants Division.

Iron and Steel Division

The April 11 meeting in Detroit will be devoted largely to conferring with representatives of the tractor and agricultural implement manufacturers on the matter of eliminating from the Standard specifications some of the present S.A.E. Carbon-Steels and possibly adding a group of bessemer steels. It is hoped, however, that Subdivision reports on Chromium and Chrome-Vanadium Steels and on Sheet Steels can be acted upon at that time. One of the important subjects in hand is Rolling Tolerances for Leaf-Spring Stock. A report on this was circulated recently in the industries for the purpose of securing comment.

Isolated Electric Lighting Plant Division

Probably the only work this Division will do is to cooperate with the Lubricants Division at the joint meeting in Chicago on April 18 on the subject of Lubricating Oil Specifications.

Lighting Division

The most important subject before this Division is Headlamp Illumination Specifications. The motor vehicle lighting committee of the Illuminating Engineering Society, with which the Lighting Division has cooperated, has submitted a revision of the present standard for the laboratory testing of automobile headlamps for proper illumination intensities and distribution of light beam. Among the subjects suggested for revision are Bases, Sockets and Connectors, Incandescent Lamps and Headlamp Mountings. It has been suggested also that Headlamp Reflectors and Focusing Mechanisms should be considered by the Division at its meeting in Cleveland on May 3.

Lubricants Division

Tentative recommendations for Crankcase Oils for passenger cars, motor trucks, motorboats and tractors, Motorcycle Oils and Transmission Lubricant Specifications that were circularized last fall probably will be reported upon definitely at the meeting in Chicago on April 18. This meeting will be held in conference with the Agricultural Power Equipment, the Engine, the Isolated Electric Lighting Plant, the Motorcycle and the Stationary Engine Divisions to reconcile the specifications to the needs of the different automotive groups.

Motorboat Division

Among the subjects assigned to this Division are Engine Support Arms, Exhaust-Manifold Connections, Tachometer Drives and Motorboat Controls (reverse gear). Motorboat electrical equipment and the tentative lubricants specifications also will be considered by it.

Nomenclature Division

This Division, which has been inactive for over 2 years, has been scheduled to meet in New York City on April 3, principally to determine upon the form in which the nomen-

clature for the parts and materials entering into the construction of various types of automotive apparatus should be published. The present S.A.E. Nomenclature for Passenger Cars, printed on pages K1 to K21 of the S.A.E. HANDBOOK, should be reviewed from the standpoints of revision, extension and correlation with nomenclatures proposed to be standardized for other automotive groups.

NON-FERROUS METALS DIVISION

A Subdivision report is expected on Aluminum Alloys, including one having a copper-content of from approximately 8.5 to 11.0 per cent, and specifications for aluminum sheet, rod and tubing. The Division will probably make definite recommendations on these subjects at its meeting in Cleveland on May 1.

PARTS AND FITTINGS DIVISION

The important subjects awaiting disposition by the Division are Ball Studs, Flexible Discs for Couplings, Gasoline-Tank Filler-Pipes and Caps, Spring Shackle-Bolts, Passenger-Car Bumper-Mountings, Cotter-Pins and Plain Washers. Subdivisions have been working on several of these subjects and current progress indicates that definite reports can be made at the Division meeting in Detroit on April 12.

PASSENGER CAR DIVISION

The most important subject on which it is probable this Division can act is Passenger-Car Front-Axle Hubs. Tentative arrangements have been made to have this Division meet jointly with the Axle and Wheels Division in Cleveland on May 2.

PASSENGER-CAR BODY DIVISION

Subdivision reports are expected on recommendations for Door-Handles, Door Hinges, Plate Glass, Windshield Side-Arms and Wood-Screw Drill-Sizes. Considerable progress has been made on several of these subjects and it is hoped that final action can be taken on them at the meeting in Detroit on May 8.

SCREW THREADS DIVISION

Although a large amount of the work assigned to this Division is related closely to that of the National Screw Thread Commission and the American Engineering Standards Committee's Sectional Committees on Screw Thread Standardization and on Bolt, Nut and Rivet Proportions, for which the Society is one of the sponsors, it is felt that progress can be made by holding the meeting set for Cleveland on May 1. A number of other subjects are listed for consideration by this Division, including Bolt and Rivet Heads, Studs, Spark-Plug Threads, Tire Valves and Machine-Screw Nuts.

SPRINGS DIVISION

At the meeting in Detroit on March 14 the present S.A.E. spring standards and recommended practices, printed in the S.A.E. HANDBOOK, commencing on page H1, were reviewed and some modifications proposed. The subjects were divided among three Subdivisions for review and report, and it is planned to take further action at the Division meeting to be held in Detroit on May 5. Perhaps the most important matter to be reported to the Standards Committee is Rolling Tolerances for Concave Leaf-Springs. This subject is under consideration also in the Iron and Steel Division, and a communication with regard to it has been sent throughout the industries by the Society.

STATIONARY ENGINE DIVISION

A number of subjects, including Crankshafts, Stationary-Engine Belt-Speeds, Flywheel Pulley Lugs and Poppet Valves, have been before this Division. It is hoped that sufficient progress will be made to permit the submission of final recommendations on a number of these subjects at the Division meeting in Chicago on May 12. The Division is scheduled also to meet with the Lubricants Division in Chicago on April 18, to pass upon recommendations for Lubricating Oil Specifications.

STORAGE BATTERY DIVISION

It is likely that this Division will take up several matters connected with electric cars and trucks, among these being Storage-Battery Jar Dimensions and Molded Hard-Rubber Containers.

TRANSMISSION DIVISION

Standardization features relating to Oiling Mechanism for Clutch Bearings, Clutch Facings and Transmission Tire-Pump Mountings are having study in Subdivisions. The Division has before it the subject of Transmission Drives for Speedometers, this being in abeyance pending the disposition of certain patent matters. It is planned to take final action on as many as possible of the subjects before the Division at its meeting in Detroit on April 13.

TRUCK DIVISION

The subjects of Body Hold-Down Clamps, Dumping-Hoist Platforms and mounting dimensions for Motor-Truck Cabs are assigned to this Division. It is trusted that sufficient data in these connections will be available to enable the Division to make definite recommendations at its meeting scheduled for Detroit on May 9.

NUMBER AND VALUE OF FARM ANIMALS

THE accompanying tables that have been compiled recently by the Department of Agriculture give the numbers and values of the different kinds of farm animals in the United States on the first day of January of the years 1920, 1921 and 1922.

During the 2 years from Jan. 1, 1920, to Jan. 1, 1922, the horses on American farms decreased in number by 667,000 and in value by $561,492,000; the mules increased in number by 9000 but decreased in value by $325,689,000; the milch cows increased in number by 306,000 but decreased in value by $811,983,000; other cattle decreased in number by 2,074,000 and in value by $892,377,000; sheep decreased in number by 2,977,000 and in value by $235,427,000; and swine decreased in number by 2,348,000 and in value by $558,269,000.

These above figures relate only to animals on farms. The numbers and values of the different kinds of animals not on farms, in cities and villages, have not been estimated by the Department of Agriculture. According to the last census, however, the number of such animals were as follows: Horses, 1,705,611; mules, 378,250; cattle, including milch cows, 2,111,928; sheep, 450,742; swine, 2,638,389.—*Economic World.*

Number

	Jan. 1, 1920	Jan. 1, 1921	Jan. 1, 1922
Horses	19,766,000	19,208,000	19,099,000
Mules	5,427,000	5,455,000	5,436,000
Cows	23,722,000	23,594,000	24,028,000
Cattle	43,398,000	41,993,000	41,324,000
Sheep	39,025,000	37,452,000	36,048,000
Hogs	59,344,000	56,097,000	56,996,000
Total	190,682,000	183,799,000	182,931,000

Value

	Jan. 1, 1920	Jan. 1, 1921	Jan. 1, 1922
Horses	$1,907,646,000	$1,619,423,000	$1,346,154,000
Mules	805,495,000	636,568,000	479,806,000
Cows	2,036,750,000	1,515,249,000	1,224,767,000
Cattle	1,875,043,000	1,316,727,000	982,666,000
Sheep	408,586,000	235,855,000	173,159,000
Hogs	1,131,674,000	727,380,000	573,405,000
Total	$8,165,194,000	$6,051,202,000	$4,779,957,000

ACTIVITIES OF THE SECTIONS

Secretaries of the Sections

BUFFALO SECTION—E. T. Mathewson, Acting Secretary, 321 Fidelity Building, Buffalo
CLEVELAND SECTION—E. W. Weaver, 5103 Euclid Avenue, Cleveland
DAYTON SECTION—R. B. May, Dayton Engineering Laboratories Co., Dayton, Ohio
DETROIT SECTION—B. Brede, assistant secretary, 1361 Book Building, Detroit
INDIANA SECTION—B. F. Kelly, Weidely Motors Co., Indianapolis
METROPOLITAN SECTION—F. E. McKone, 347 Madison Avenue, New York City
MID-WEST SECTION—T. Milton, 140 South Dearborn Street, Chicago
MINNEAPOLIS SECTION—C. T. Stevens, Reinhard Brothers Co., Minneapolis
NEW ENGLAND SECTION—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston
PENNSYLVANIA SECTION—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
WASHINGTON SECTION—B. R. Newcomb, 211 Victor Building, City of Washington

PRESIDENT BACHMAN has suggested that the Sections could perform a valuable service by scheduling for consideration from time to time at their meetings the standardization work under way in the Society. While it is felt that the members comprising the various Divisions of the Standards Committee are undoubtedly representative of the most authoritative engineering knowledge and opinion in their respective fields, it is nevertheless apparent that no opportunity should be lost to bring to the attention of all members of the Society certain proposed standards in order that the Standards Committee may have before it the thoughts and conclusions of as wide a circle as possible, before final action is taken.

Perhaps an even greater service can be rendered by the Sections in conducting discussion of the standards that have been established, with a view to increasing their use where they are applicable, or modifying them if necessary to increase their general usefulness.

With these ideas in mind, a number of the Sections have been asked to give attention at their current meetings to certain proposed new standards or modifications of old ones. The subjects have been chosen with reference to their appropriateness in connection with papers to be presented at the respective Section meetings, so that among those attending there may be a number well qualified to present views on the particular Standards matter under consideration.

Standards matters for discussion in connection with papers presented or to be presented include:

Section	*Subject of Paper*	*Standard*
Buffalo March 21	Electric Wiring Systems—W. S. Haggott	Electrical Fittings, such as cable connectors, clamps and junction boxes
Pennsylvania March 23	Batteries and Electrical Equipment	General discussion of present battery standards and suggestion of modifications to promote their greater use
Metropolitan March 23	Truck Rear-Axles—E. Favary	Discussion of the possibility of standardization with respect to rear-axles
Minneapolis April 5	Tractor Publicity and Demonstrations	Application of S. A. E. Standards to tractors and their value to the tractor industry.
Detroit April 21	Crankcase Oil-Dilution Problems and Their Solution—W. F. Parish	Discussion of tentative oil specifications of the Lubricants Division

RECENT MEETINGS

At the meeting of the Minneapolis Section at the Manufacturers' Club on March 1 A. W. Scarratt spoke on Development in Automotive Transportation and Equipment;

Schedule of Sections Meetings

APRIL

5—MINNEAPOLIS SECTION — Tractor Publicity and Demonstrations

7—WASHINGTON SECTION — Automobile Headlight Problem—Dr. E. C. Crittendon

14—MID-WEST SECTION — Various Commercial Fuels and Their Relative Characteristics

21—METROPOLITAN SECTION — NEW ENGLAND SECTION — Joint meeting at New Haven, Conn. Inspection of laboratory equipment; and description of methods used in determining losses from the engine to the road, by Prof. E. H. Lockwood

21—DETROIT SECTION — Crankcase Oil Dilution Problems and Its Solution—William F. Parish

21—CLEVELAND SECTION — Motor-Vehicle Lighting—H. H. Magdsick

27—PENNSYLVANIA SECTION—Motor Trucks and Transportation—C. T. Myers

MAY

12—MID-WEST SECTION—Fundamental Losses in Automotive Apparatus—Their Magnitude and Reduction Possibilities

19—DETROIT SECTION—Cylinder-Wall Surfacing Methods

25—PENNSYLVANIA SECTION — Either Outing at Torresdale or Body Meeting

E. R. Greer treated the phase of automotive transportation relating to trailers; and Dr. C. A. Prosser gave an address on the Profession of the Engineer.

At the Cosmos Club on March 3 A. W. Herrington, automotive engineer, Quartermaster Corps, U. S. A., gave an account of his experiences with Small High-Efficiency Air-Cooled Engines. His talk was illustrated.

In the opinion of a number of those who were present, the paper on Air-Cooled Cylinder Design presented by S. D. Heron at the Dayton Section meeting on March 7 was very clear and comprehensive. Several officers of the Society, who had attended a Council meeting in Dayton during the day, were present. At the dinner preceding the meeting at the Engineers' Club, President Bachman and Past-President Beecroft addressed the members and their guests, Capt. G. E. A. Hallett, chairman of the Section, presiding. About 400 attended the meeting.

A paper of rather unusual interest was that given by A. C. Vauclain before the Buffalo Section, Feb. 21, on Resilient Wheels. At the meeting of this Section on March 21 W. S. Haggott presented a paper on Electric Wiring Systems for Automobiles, which, together with the discussion growing out of it, will probably form a basis for action by the Electrical Equipment Division of the Standards Committee.

F. H. Tower spoke before the Cleveland Section on Feb. 17, on Commercial and Laboratory Methods of Testing Ignition. Plans are now under way for the Cleveland Section's share in the festivities that will take place during the Summer Meeting of the Society at White Sulphur Springs. According to a wireless telephone conversation recently held with L. L. Williams, the efficient press agent of the Section, the Cleveland stunt this year will be the "greatest show on earth; bigger and better than ever." Those who saw last year's performance will be inclined to agree that they will stage some very much worthwhile foolishness. At the March 17 meeting of the Section William T. Walker gave a paper on Truck Axles.

Scarcely a month passes in which at least one of the Sections does not contribute something toward the general understanding of the business situation. C. C. Parlin spoke before the New England Section at the Boston Engineers' Club on March 17, having as a subject, Business Aspects of the Automotive Industry.

Ethelbert Favary, at the Metropolitan Section meeting of March 23, presented a review of the various designs of truck rear-axle. Cornelius T. Myers brought up the matter of the desirability of standardization in this quarter. On the same evening the Pennsylvania Section discussed Batteries and Electrical Equipment at the Philadelphia Engineers' Club. The speakers were T. W. Hearne, who gave a paper on Storage Batteries from the Service Standpoint; A. K. Brumbaugh, who related some phases of the truck lighting problem; and L. P. Neal, who discussed electrical units from the service viewpoint. There was also a general discussion of the present S.A.E. storage battery standards with a view to bringing out any constructive criticism.

In the light of the necessity for lowering in every way all costs entering into car construction that do not add to the quality of the output, production matters are assuming increased importance. The Detroit Section has realized this and expects to hold a number of meetings on various production problems during the coming months. The first of the series was held on March 24.

The Detroit Section meeting of Feb. 24 was on the subject of Light-Weight Pistons and Piston-Ring Design. Several short papers were presented, these being by John Magee, Charles R. Manes, James E. Diamond, Ferdinand Jehle and Frank Jardine.

A large number of railroad and street-car operating officials were invited by the Indiana Section on March 29 to inspect a gasoline engined railroad-car that was driven from Wabash to Indianapolis. The demonstration was followed by a dinner at the Indianapolis Chamber of Commerce, after which Charles O. Guernsey gave a highly interesting paper on railroad motor cars.

OBITUARY

WALTER A. SCHUEHLE, road-inspection engineer for the Lexington Motor Co., died, Jan. 3, 1922, aged 36 years. He was born, Jan. 13, 1885, at Chicago. Following his preliminary training, he became chief inspector for the Overland Motor Car Co. in 1907 and continued inspection work with this company until 1910, with the Federal Motor Works from 1910 to 1914, and with the Lyons Atlas Co. from 1914 to 1915. He was then with the National Motor Vehicle Co. until 1916, when he became traveling engineer for the Cole Motor Car Co.

His war service was inclusive of work for the Signal Corps as aeronautical mechanical engineer and for the Bureau of Aircraft Production as assistant consulting engineer of armament. In the latter work he was associated closely with A. L. Nelson and, when Mr. Nelson left the service, Jan. 15, 1919, Mr. Schuehle succeeded to his position.

Mr. Schuehle did much of the testing in connection with the development of the Nelson gun control and was responsible also for many of the design changes in the Marlin, Vickers and Browning aircraft guns. After leaving the service of the Government, he became an inspection engineer for the General Motors Co., at Walkerville, Ont., Canada, his last position being with the Lexington Motor Co. He was elected to Member grade in the Society, Oct. 30, 1918.

Current Standardization Work

A MEETING of the Iron and Steel Division was held in New York City on Feb. 21, at which several subjects mentioned hereinafter were discussed, but no final action taken thereon. The Springs Division held on March 14 in Detroit a meeting at which a program for the year was laid out, Subdivisions being appointed in order to facilitate the work.

Standards Letter Ballot

The results of the letter ballot on the adoption of the standards acted upon at the January Standards Committee Meeting are given on page 260 of this issue.

Ball Bearings

The following requests have been submitted by the Sectional Committee on Ball Bearings of the American Engineering Standards Committee, hereinafter called the Sectional Committee, to the sponsor bodies, the Society of Automotive Engineers and the American Society of Mechanical Engineers. These requests will be considered at the next meeting of the Ball and Roller Bearings Division.

Extra-Light Series.—The Sectional Committee has requested that the Society investigate the German extra-light series of annular ball bearings and give careful consideration to the advisability of establishing a corresponding S. A. E. Standard.

Light Series, Extra Large.—The Sectional Committee has requested that the Society make a careful study of the proposed German standard and if possible change the outside diameters for the present S. A. E. Standard extra-large light-series bearings to agree with the outside diameters adopted by the German Standards Committee; and that the widths adopted by the German Committee should be thoroughly considered. The Sectional Committee believes, however, that the narrow widths will not permit satisfactory design of radial bearings carrying an appreciable thrust-load and that they are not suitable for the design of double-row ball bearings with spherical outer races.

Medium Series, Extra Large.—The Sectional Committee has requested that the Society make a careful study of the proposed German standard and if possible change the outside diameters of the present S. A. E. Standard extra-large medium-series bearings to agree with the outside diameters adopted by the German Standards Committee.

Heavy Series.—The Sectional Committee has requested that the Society make a careful study of the proposed German Standard and change the outside diameters for S. A. E. bearings above 85-mm. bores of the heavy series to agree with the outside diameters adopted by the German Standards Committee.

Wide Type.—The Sectional Committee has requested that the Society consider (*a*) changing the outside diameters of the light, medium and heavy series double-row bearings to conform with such outside diameters as are finally adopted for the single-row bearings; (*b*) changing the S. A. E. Standard to bring the widths of the S. A. E. and German standards together, or to change the inch widths to millimeters; (*c*) investigating the possibility of a demand in America for a narrower series of double-row ball bearings than the present S. A. E. Standard.

The Sectional Committee suggests that in studying the possible change of outside diameters the Society endeavor to omit some of the intermediate sizes, particularly in the heavy series, and that the outside diameters of the series be selected so that as few outside diameters as possible are necessary, to reduce the necessary tool equipment.

Corner Radii.—The Sectional Committee has requested that the Society consider changing the S. A. E. Standards so that they will conform with the corner radii adopted by the German Standards Committee, particularly in view of the fact that it is stated that the S. A. E. corner radii are too small.

Tolerances.—The Sectional Committee has requested that the Society consider the German standard width-tolerances and indicate what recommendation should be made for standard width-tolerances in American practice, as well as what would be the result in America if the closer German tolerances were adopted.

Ignition-Distributor Mountings

The present S. A. E. Standard for Ignition-Distributor Mountings, page B16, S. A. E. Handbook, specifies that the distance from the base of the distributor body to the end of the coupling tongue shall "vary to suit conditions."

As it was thought that this dimension should be standardized, a Subdivision of the Electrical Equipment Division was appointed to circularize ignition-distributor manufacturers and users and to recommend a revision of this standard based upon the data obtained. W. A. Chryst was appointed to carry on this work and has recommended that the following revisions be made in the present S. A. E. Standard

(1) Specify a dimension of 27/32 in. for the distance from the base of the distributor body to the end of the coupling tongue of the Type-B ignition-distributor

(2) Change the limits for the bore of the collar from 0.4930 in. maximum and 0.4920 in. minimum to 0.4915 in. maximum and 0.4905 in. minimum

The dimension of 27/32 in. is in accord with present practice. The revision in limits does not affect the actual manufacturing tolerances now specified for each part, but results in closer fits, 0.0020 in. maximum and 0.0005 in. minimum instead of 0.0035 in. maximum and 0.0020 in. minimum, between the collar and the shaft. As it is thought that the fit of the tongue and the groove is more important than that of the collar and the shaft because there is more wear between the former than between the latter, no revisions of the present limits are recommended.

Passenger-Car Bumpers

In 1921 a questionnaire was sent to passenger-car builders as to the feasibility of standardizing a plain bolted-on connection for passenger cars using the conventional type of pressed-steel frame. Although it was pointed out that the adoption of such a standard would necessitate providing holes in the passenger-car frame in conformity with whatever standard was proposed, these holes to be used either by the passenger-car builders for mounting bumpers as standard equipment or by the owners for mounting bumpers as accessories, over 90 per cent of manufacturers replying to the questionnaire recommended the formulation of such a standard bumper-mounting.

A Subdivision, consisting of F. G. Whittington and E. W. Weaver, was therefore appointed to formulate a preliminary recommendation and has recently submitted the recommendation given in Fig. 1.

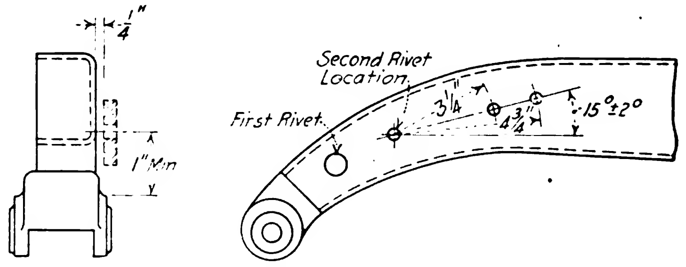


Fig. 1—Proposed Recommendation for Passenger-Car Bumpers

Two 33/64-in. diameter bolt-holes shall be located on or near the neutral axis of the frame section

The first bolt-hole from the frame horn shall coin-

cide with the first or second rivet hole and shall be located at least 1 in. above the frame-horn lug. Clearance must be provided for the bolt-head inside of the frame channel

The second bolt-hole shall be located on a line passing through the center of the first bolt-hole at an angle of 15 deg. plus or minus 2 deg. above the horizontal and at a distance from the first bolt-hole of from 3¼ to 4¾ in. In cases where the second bolt-hole is to be used for mounting a shock-absorber, the hole shall be located not more than 1 7/16 in. from the bottom of the frame channel at the nearest point

There should be normally a clearance of ¼ in. between the side-rail and bumper bracket so that the latter will clear the rivet-heads

In case passenger cars are not equipped with bumpers as standard equipment, it is intended that a flat-headed bolt shall be used in place of the first or second rivet to facilitate mounting bumpers as accessories.

Iron and Steel Specifications

The matters outlined below were brought out at the February Iron and Steel Division meeting.

Chemical Compositions.—The suggestion made by E. A. Johnston, of the International Harvester Co., to reduce the standard carbon-steels to the least number required was discussed in considerable detail in connection with present practice among steel producers and parts manufacturers. A conference on the subject is to be arranged between the members of the Division and representatives of the International Harvester Co. and other implement manufacturers.

It was stated that at the present time there is no composition in the carbon-steel group suitable for steel spring wire. The steel used by the steel-wire manufacturers ranges around 0.65 per cent carbon and 0.75 to 1.05 per cent manganese, but it is thought that if there were an S. A. E. Steel designated as Steel 1065 concerted effort among steel mills would practically bring about its universal use. S. A. E. Steel 6150 is easily obtainable and used to some extent for the purpose in mind, but the greater volume of spring wire is made from carbon-steel. It is understood that the steel-wire mills required the specially high manganese-content in the carbon-steel because of difficulties in the drawing operations encountered with lower-manganese steels.

Although the work of the Iron and Steel Division so far has been related to steel compositions for forging purposes rather than to compositions for special purposes such as spring wire, it is felt by the members of the Division that the suggested subject should be taken up. Chairman Gilligan appointed the following Subdivision to investigate the practice among the various steel wire mills and to prepare a tentative report for consideration by the Division:

L. A. Danse, chairman	Cadillac Motor Car Co.
W. C. Peterson	Atlas Crucible Steel Co.
C. F. W. Rys	Carnegie Steel Co.
E. W. Stewart	William D. Gibson Co.

Bessemer Steels.—Attention was given to the subject of standardizing bessemer-steel specifications, as the following comments had been submitted:

> Outside of S. A. E. Steel 1112, screw-stock, which could be a bessemer steel, the automotive engineers are strongly in favor of the open-hearth process, due largely to the low phosphorus-content possible in open-hearth steels. However, the attitude toward bessemer stock is not altogether justified, as perhaps 85 per cent of the steel going into the products of a large number of the implement manufacturers is bessemer steel

The opinion was expressed that if bessemer steels were included in the specifications, there would be danger of automobile manufacturers using them when open-hearth steels are not readily obtainable. The Division members present were of the opinion that it would be unwise to mix steels such as the bessemer types, which are used by the agricultural-implement manufacturers, with those now included in the S. A. E. Steel Specifications which are used by the automobile and tractor industries. As it was deemed inadvisable to make a final decision, it was voted to table the subject until further information shall have been received.

Cast Iron.—The suggestion that the Division take up the matter of the adoption of standard specifications for cast iron was discussed. Previous attempts of the Division to prepare such specifications were mentioned and the opinion expressed that before the subject is taken up, tentative specifications for as many grades of cast iron as may be considered necessary should be submitted. It was noted that the tendency is toward specifying the grades of cast iron according to the Brinell hardness instead of by chemical analysis.

Sheet Steel.—A progress report was submitted from W. C. Peterson that data are being collected for a general specification for sheet steel and that a tentative report should be ready for consideration by the Division at the next meeting.

Leaf-Spring Stock

At the Iron and Steel Division meeting held on Oct. 21, 1921, M. P. Rumney explained that the spring manufacturers had felt that there is need for further standardization by the Society. It was indicated that the Leaf-Spring Group of the Motor and Accessory Manufacturers Association could accomplish much by suggesting to the Springs Division of the S. A. E. Standards Committee certain subjects for standardization or in some cases submitting recommendations to the Springs Division for consideration and adoption by the Society.

Mr. Rumney stated that under present conditions there is lack of uniformity of practice in rolling leaf-spring stock and that the following proposal, which had been submitted by the Leaf-Spring Group, is the best compromise that could be made between the varying practices in different mills. It was decided to circularize the proposal among manufacturers and users of leaf-springs for comment.

ROLLING TOLERANCES FOR CONCAVE AUTOMOBILE SPRING STEEL

The finished bars shall be of double-concave section with round edges. The radii of the arcs of the two concave surfaces shall be of equal length

Rolls to produce the round edges shall be turned to a radius equal to two-thirds the thickness of the bar

All bars ordered to gage shall be rolled to the Birmingham wire gage

All bars must meet the width and thickness tolerances specified in Table 1

TABLE 1—WIDTH AND THICKNESS TOLERANCES

Width of Flat, in. Over	Width of Flat, in. To, Inclusive	Width, in. Plus	Width, in. Minus	Thickness,[1] in. Plus	Thickness,[1] in. Minus
0	2¼	1/32	0	0.005	0.005
2¼	3	3/64	0	0.006	0.006
3	5	1/16	0	0.007	0.007

[1] Thickness measurement to be taken at edge of bar where concave surface intersects round edge.

The difference in thickness between the two edges of each bar shall not be greater than those given in Table 2

TABLE 2—DIFFERENCES IN THICKNESS

Width of Flat, in. Over	Width of Flat, in. To, Inclusive	Difference in Thickness, in.
0	2	0.002
2	3	0.003
3	5	0.004

Spring-steel bars shall not have more than 1-in. curvature in 20 ft., or 1¼ in. in 25 ft., or 1½ in. in 30 ft.

The concavity, the difference between the thickness at the edges and at the center of the bar, shall be as specified in Table 3

TABLE 3—ALLOWABLE VARIATIONS IN CONCAVITY

Width, in.	Nominal Concavity, in.	Maximum Concavity, in.	Minimum Concavity, in.
1½	0.007	0.009	0.004
1¾	0.008	0.010	0.005
2	0.010	0.012	0.006
2¼	0.011	0.013	0.007
2½	0.013	0.015	0.009
3	0.016	0.018	0.012
3½	0.018	0.020	0.013
4	0.021	0.023	0.016
5	0.029	0.031	0.023

Motorboat Controls

Further standardization of motorboat controls has been suggested, it being stated that

> The only reverse control provided on all marine engines as equipped at the present time is the standard reverse lever keyed to the reverse-gear jackshaft. This lever has been, and is, the only reverse control provided since the installation of the first reverse-gear. It would be helpful if a standard reverse-control mechanism could be provided on all standard marine engines so that the motorboat builder could connect standard bridge-deck controls direct to the engine builders' control equipment, which it is impossible to do on any standard marine engine today, for it is necessary for the motorboat builder to throw the regular reverse lever away and build his own controls from the bridge-deck control position all the way to the reverse-gear.
>
> The same conditions apply in every respect to the spark and throttle controls, as the engine builders only provide brass levers here and there wherever they can be mounted.

Passenger-Car Frames

At the November 1921 meeting of the Frames Division the present S. A. E. Recommended Practice for Passenger-Car Frames was reviewed and it was found that, although certain parts of the recommended practice are still in accord with present practice, much is obsolete.

As it is believed that a standard consonant with present practice would be of material assistance to many passenger-car designers and to the frame manufacturers, owing to the fact that frequently a car builder is willing to use whatever frame the frame manufacturer is tooled for which will meet with his requirements, it was decided to circularize the industry for information as to present passenger-car frame practice.

There is a tendency in some instances toward the use of frames with straight and parallel side-members. If the data received indicate a sufficient use of this type of frame to warrant its standardization, it should perhaps be covered by the Division recommendation. Data that have been obtained by the Society have been referred to a Subdivision for preliminary study.

Magneto Mountings

The standardization of magneto mountings for stationary engines, isolated electric-lighting plants and small tractors is one of the most important problems before the Electrical Equipment Division. At the meeting held recently in Chicago by the Subdivision appointed to formulate a recommendation a preliminary proposal, Fig. 2, was approved. This has been submitted to engine and magneto manufacturers for comment.

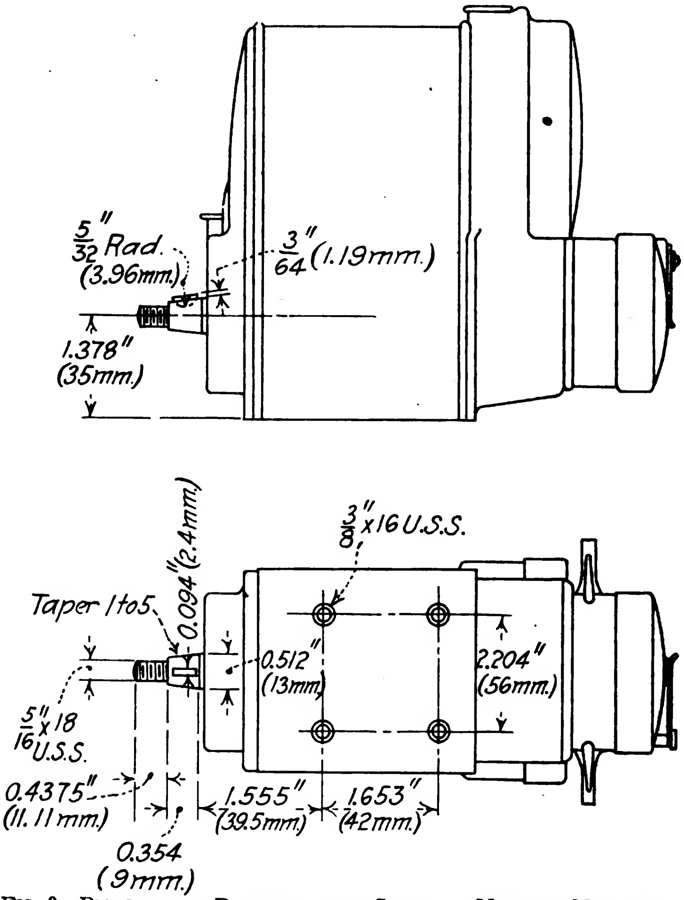


Fig. 2—Preliminary Proposal for a Standard Magneto Mounting

The proposal, together with all comments received, will be considered at the next meeting of the Electrical Equipment Division.

BUSINESS AND ENGINEERING

The perennial controversy between engineering production and sales indicates something amiss in the system of education and training that is intended to turn out men who are able to pull together and see each other's viewpoint. Members who are specially concerned with this phase of business engineering may be interested in learning that the United States Commissioner of Education is calling a second public conference on commercial engineering on behalf of a committee on commercial engineering appointed by him to investigate business training of engineers and engineering training for students of business.

The conference will be held May 1 and 2 at the Carnegie Institute of Technology in Pittsburgh. President Arthur Hamerschlag of that institution is a member of the committee, which is composed of deans of prominent schools of engineering and commerce in our larger universities, and of engineers and business men who are nationally known for their interest in the reduction of the costs of production, distribution and transportation, through better training in schools and colleges of the personnel of industry and commerce. The conference will be open to the public. Invitations to appoint delegates to the Pittsburgh conference will be sent, however, by the Commissioner of Education to commercial and trade organizations, engineering and scientific societies, educational institutions and other groups, as well as to prominent individuals.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 10 and March 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

BARCLAY, ERIC (A) merchant, Teal & Co., Inc., *Manila, P. I.*

BROAD, ROBERT E. R. (E S) student, Armour Institute of Technology, Chicago, (mail) *Chesterton, Ind.*

CLARKE, JAMES RUSSELL, JR. (J) student, Cornell University, *Ithaca, N. Y.*, (mail) 2 Central Avenue.

CROSSMAN, S. B. (J) assistant service engineer, Detroit Cadillac Motor Car Corporation, New York City, (mail) Chichester Avenue, *Hollis, N. Y.*

DEMPSEY, WILLIAM L. (M) president, and consulting engineer Dempsey Cycle Co., 618 Perry Building, *Philadelphia.*

DODSHON, FRED GEORGE (A) by-products, General Motors Corporation, *Detroit*, (mail) 819 Longfellow Avenue.

DOMJAN, RALPH (J) designer of tools, jigs, fixtures and experimental parts, Detroit Cadillac Motor Car Corporation, 245 West 67th Street, *New York City.*

DURLAND, HARRY S. (J) instructor and technical salesman, Double Seal Ring Co., New York City, (mail) 63 Hinsdale Place, *Newark, N. J.*

FARQUHARSON, F. B. (J) student, University of Washington, *Seattle, Wash.*, (mail) 5236 21st Avenue, N. E.

FEZANDIE, EUGENE H. (E S) student, Columbia University, *New York City*, (mail) 165 East 66th Street.

GAA, VICTOR H. (A) designing and experimental engineer, Edmunds & Jones Corporation, 4440 Lawton Avenue, *Detroit.*

GERMAN, JOHN WESLEY (A) assistant treasurer, Detroit Cadillac Motor Car Corporation, 1881 Broadway, *New York City.*

GREENHOE, CLAUDE (M) engineer, motor bearings division, Hyatt Roller Bearing Co., *Detroit*, (mail) 209 Philip Avenue.

GRUENBERG, WALTER H. (E S) student, Tri-State College, *Angola, Ind.*, (mail) 509 West Maumee Street.

HAINES, W. S. (A) experimental engineer, Mercer Motors Co., Whitehead's Road, *Trenton, N. J.*

HAMMEL, JACOB (M) body engineer, Packard Motor Car Co., *Detroit*, (mail) 7405 Hanover Avenue.

HARRY, GORDON W. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 407 East University Avenue.

HAYES, HAROLD W. (A) division engineer, Dodge Bros., *Detroit*, (mail) 293 East Canfield Avenue.

HOUSER, JESSE E. (M) chief inspector, Delco-Light Co., *Dayton, Ohio*, (mail) R. F. D. No. 7.

HUGGINS, E. MELVILLE (M) chief engineer, Snead & Co., Jersey City, N. J., (mail) 27 Washington Square, North, *New York City.*

JONES, LESTER G. (E S) student, Columbia University, New York City, (mail) 851 President Street, *Brooklyn, N. Y.*

KIMBELL, ARTHUR W. (A) secretary and general manager, Cinch Fastener Corporation, 2335 West Van Buren Street, *Chicago.*

KOHL, J. J. (A) assistant manager, City Machine & Tool Works, *Dayton, Ohio*, (mail) 1030 Arbor Avenue.

KOPSHAC, J. C. (A) general mechanical superintendent, Detroit Cadillac Motor Car Corporation, New York City, (mail) 810 Ely Avenue, *Long Island City, N. Y.*

LEAVITT, DUDLEY W. (J) purchasing agent, Commodore Motors Corporation, *New York City*, (mail) 861 Hornaday Place.

LILLIBRIDGE, H. W. (J) engineering department, Atwater Kent Mfg. Co., *Philadelphia*, (mail) 4820 Greene Street.

LINDSTROM, CARL T. (E S) senior student in mechanical engineering, Rensselaer Polytechnic Institute, *Troy, N. Y.*

MARSHALL, WILLIAM J. (A) 765 Lincoln Place, *Brooklyn, N. Y.*

NAKADA, KYOICHI (F M) assistant chief designer, Azomuna-Kibigori, *Okoyamaken, Japan.*

O'CONNOR, THOMAS A. (A) service manager, Western Motors Co., *Los Angeles, Cal.*, (mail) 1029 South Hope Street.

PEAVEY, CLARENCE W. (A) instructor in technical and practical automobile repairs, Main Avenue High School, *San Antonio, Tex.*, (mail) 324 Maverick Street.

REUTER, IRVING J. (M) general manager, Remy electric division, General Motors Corporation, *Anderson, Ind.*

RICH, RALPH E. (A) president and chemical engineer, Amalgamated Metals Co., *Chicago*, (mail) 673 Sheridan Road.

RIEGER, EARL CHARLES (E S) student, Armour Institute of Technology, *Chicago*, (mail) 2620 North Lawndale Avenue.

SEMINO, ANGELO F. (E S) student, Leland Stanford University, Stanford University, Cal., (mail) R. F. D. No. 2, Box 141, *Mountain View, Cal.*

TIFFANY, HALSTED R. (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 57 Second Street.

WINQUIST, GEORGE WALTER (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 128 12th Street.

WORLEY, LEE (A) chief draftsman on drawings for the Barling bombing plane, Witteman Aircraft Corporation, Hasbrouck Heights, N. J., (mail) 13 Myrtle Avenue, *Newark, N. J.*

WRIGHT, BENJAMIN F. (J) chief draftsman, Wright-Fisher Engineering Co., *Detroit*, (mail) 20 Elmhurst Avenue.

YAMAGATA, J. (F M) gasoline engine designer, Tokyo Gas & Electric Co., *Tokyo, Japan*, (mail) No. 77 one chome Nihonenoki machi.

ZEDER, JAMES C. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 1824 Geddes Avenue.

Applicants *for* Membership

The applications for membership received between Feb. 25 and March 15, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALVUT, EDMOND JONES, student, Rensselaer Polytechnic Institute, *Troy, N.Y.*

ANDERSON, NELS G., chief engineer, International Harvester Co., *Chicago.*

BACON, ELBRIDGE F., student, University of Michigan, *Ann Arbor, Mich.*

BROOKS, DONALD B., student, Ohio State University, *Columbus, Ohio.*

BROWN, RONALD J., assistant secretary, Tracking Trailer Co., *Cleveland.*

CHAFFEE, FLOYD O., automotive engineer, Los Angeles Automotive Works, *Los Angeles, Cal.*

CLEMENTS, MENEFEE R., secretary, treasurer and general manager, Clements-Steele Tobacco Co., *Owensboro, Ky.*

DANIEL, E. H., president and general manager, London Motor Plow Co., *Springfield, Ohio.*

DEFRANCE, SMITH J., student, University of Michigan, *Ann Arbor, Mich.*

DORAN, FELIX, JR., special representative, Chevrolet Motor Co., *Kansas City, Mo.*

FARRIS, MARTIN W., foreman mechanic, Studebaker Corporation of America, *Brooklyn, N. Y.*

FUI KAU, PHILIP, student, Pratt Institute, *Brooklyn, N. Y.*

GATOFF, JOHN HENRY, body engineer, Continental Body Corporation, *Hempstead, N. Y.*

GOERK, EDWARD G., United Y.M.C.A. Schools, 347 Madison Avenue, *New York City.*

GRAHAM, WELLINGTON R., chief engineer, Kelland Motor Car Co., *Newark, N. J.*

GRUNDMANN, WILLIAM R., service manager, Walter S. Halliwell, Inc., *East Hartford, Conn.*

HABERKOST, NOEL F. C., student, Ohio State University, *Columbus, Ohio.*

HEADLEY, LEWIS M., student, Ohio State University, *Columbus, Ohio.*

HECKMAN, WILLIAM, secretary, Heckman Signal Co., *St. Louis.*

KELLER, K. T., manager of manufacturing, Chevrolet Motor Co., *Detroit.*

KOOLHOVEN, FREDERICK, consulting engineer, Spyker Works Amsteldyk, *Amsterdam, Holland.*

LEIGHTON, HARRY R., assistant general manager, Interstate Foundry Co., *Chicago.*

LYNAH, JAMES, vice-president, Barnard-Lynah, Inc., *New York City.*

MAPEL, LEWIS A., vice-president and general manager, Automatic Appliance Co., *St. Louis.*

MEDDAUGH, RAY G., technical department, service division, Dodge Bros., *Detroit.*

MORRIS, EDWARD E., student, Ohio State University, *Columbus, Ohio.*

OSGOOD, FRANK G., aeronautical designer, Air Service, McCook Field, *Dayton, Ohio.*

PARKHILL, JAMES, plant manager, Armstrong Spring Co., *Flint, Mich.*

PICKARD, ALFRED E., assistant manager, L. Lawrence & Co., *Detroit.*

REYNOLDS, M. S., instructor, Manual Arts High School, *Los Angeles, Cal.*

RICK, EDWARD L., engineer, H. S. Honigsberg & Co., *Peking, China.*

STALEY, ALLEN C., associate professor of gas and automotive engineering, Purdue University, *Lafayette, Ind.*

STRICKFADEN, AL. I., draftsman, 432 Clarendon Street, *Newark, Ohio.*

TABER, MELBERT W., special representative, Motor Wheel Corporation, *Lansing, Mich.*

TAWES, JACOB C., instructor, Motor Transport School, *Camp Holabird, Md.*

WHITEHEAD, C. I., managing director, Automobile Electric Supply Co., *Johannesburg, Union of South Africa.*

WOLCOTT, R. G., vice-president, Victor Bearings Co., *Indianapolis.*

THE

JOURNAL
OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 *W.* 39*th St., New York*

Issued monthly, 50 cents a number, $5 a year; foreign $6 a year; to members, 25 cents a number, $2.50 a year. Entered as second-class matter, Aug. 28, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1913.

B. B. BACHMAN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. X MAY, 1922 No. 5

INDEX

Activities of the Sections		431
Alcohol for Fuel		364
Allied Debts		439
Applicants for Membership		440
Applicants Qualified		441
Chronicle and Comment		303
Corrosion of Chromium Steels		414
Cotton Industry		368
Current Standardization Work		433
Discussion of Papers at the Annual Meeting		369
Economics of Motor Transport — Merrill C Horine		415
Government Aid for Aviation		413
Molecular Movements During Combustion in Closed Systems — Thomas Midgley, Jr		357
Motor Fuel from Coal		414
Oxygen in Iron		414
Paint Protection for Wood — Cornelius T. Myers		348
Personal Notes of the Members	Adv Section	2
Photographic Recording of Engine Data —Augustus Trowbridge		351
Publications of Interest to S A E Members		430
Recent Research Work on the Internal-Combustion Engine — Harry R Ricardo		305
S A E Employment Service	Adv Section	48
Some Notes on the California Top — P W Steinbeck		366
Summer Meeting		345
Tractor Market — J S Clapper		337
Use of Molybdenum Steel in the Automotive Industry — John D Cutter		340
Washington Conference		365

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. X May, 1922 No. 5

Chronicle and Comment

May Council Meeting

THE next meeting of the Council of the Society will be held in Indianapolis on Monday, May 8. A meeting of the Indiana Section is scheduled for the evening of the same day. The Council did not meet during April.

1922 Roster

THE 1922 edition of the Roster of the Society, containing alphabetical lists of the members and of the companies with which they are associated, as well as a section arranged according to the residence of the members, will be ready for delivery within a few weeks. The book will be issued as of April 1, all of the changes of address having been made therein that it has been possible for the office of the Society to secure before that date. Copies of the roster have been ordered by about 2500 members of the Society.

Alcohol for Motor Fuel

THIS month the suggestion of the Research Department of the Society for study by the members is alcohol for motor fuel. On page 364 of this issue of THE JOURNAL a statement of the necessity for meeting the necessary conditions of the utilization of alcohol in automotive products exported from this Country, and a very suggestive if not entirely complete outline of the points of engine design and fuel characteristics involved, are given. The importance of the subject in foreign trade was brought up at the conference convened by Secretary Hoover at the Department of Commerce last month.

Ricardo Paper

MANY members will want to read carefully the paper by Harry R. Ricardo, presented at the January meeting of the Society. This appears on page 305, together with the discussion thereon. The paper has been revised by Mr. Ricardo since it was preprinted, and is, of course, very valuable for study by all interested in features of automotive-engine design and the utilization of currently available fuels therefor. The Council of the Society, on behalf of the members, has transmitted to Mr. Ricardo its sincere thanks in engrossed form for his highly noteworthy contribution to our records.

Summer Meeting

FACTS that the members should know about the meeting of the Society to be held at White Sulphur Springs next month are given on page 345.

Six technical sessions have been arranged and the Meetings Committee has arranged for 16 papers to be presented at them. Reduced transportation rates have been secured from all points to White Sulphur Springs. A well organized Sports Committee is planning a very attractive program and the Entertainment Committee is arranging many events that will appeal to the ladies, as well as the men. At this moment 421 reservations have been received and the choicest accommodations are being taken fast.

Standards Work

A COMPREHENSIVE account of the current standardization work of the Society is given on page 433 of this issue of THE JOURNAL. Brief statements are made with regard to the Division meetings that were held last month, and a tentative schedule of May meetings is given. A number of important subjects, including automobile wiring; ball studs; clutch elements; cotter-pins; battery trays and terminals, charging plugs and receptacles and incandescent lamps for electric vehicles; emergency rim-clamps; felt specifications; front-axle hubs; gasoline-tank openings; generator and starting-motor flange mountings; ignition distributor mountings; involute splines; magneto mountings; motorboat elements; pipe fittings; plate glass; roller chains; and leaf spring elements, are treated, and members interested in any of these matters should read the article carefully.

Part II, 1920 Transactions

IT is expected that Part II of Vol. 15 of the TRANSACTIONS, containing about 800 pages, will be ready for distribution to the members during the latter part of this month. It will be recalled that this volume will be furnished to only those members who have sent a written order for it to the office of the Society, order blanks for the purpose having been published and sent

to the members repeatedly. Less than one-third of the members of the Society have signified their desire that this part of the TRANSACTIONS be sent to them. It includes, in addition to miscellaneous reports, the papers and discussions presented at the 1920 Ottawa Beach Meeting of the Society and at various Sections Meetings, that are considered of sufficient engineering and reference value to be recorded in the Transactions, as well as published in THE JOURNAL.

Employment Service

THE Employment Service conducted by the Society has, it is believed, been much improved recently. The attempt is being made to keep in as close touch as possible with companies needing men and with men seeking positions. An added feature of the service is a Semi-Weekly Bulletin mailed to both companies and men. Employing companies have shown a marked interest in this frequent bulletin service and are selecting many Society members for positions they have available. The companies are not willing in all cases to make public announcement of openings with them. It is therefore advisable that all members desiring positions should send to the office of the Society full information as to their desires and qualifications, in the manner set forth in the notes appearing at the top of the S. A. E. Employment Service column in THE JOURNAL.

Membership Increase

DURING the first four months of 1921, 324 applications for membership in the Society were received. This year, up to April 24, 238 applications were received. The Membership Committee, under the chairmanship of Lon R. Smith, is proceeding actively with the purpose of adding to the membership in a sound way that will be helpful to the industry and the public, as well as the members themselves. Many prominent executives in the automotive industries who have not taken an active part in the Society's work heretofore are showing a decided interest in its affairs. In addition to corresponding with a large number of executives, the Membership Committee is in communication with several hundred men whose names have been submitted by members of the Society on the basis that it is desirable that they be enrolled for the general good.

Highway Research

SEVERAL phases of the highway problem merit discussion by the recently established Highways Committee of the Society, of which the following are members:

H. W. Alden, chairman
W. A. Brush
G. A. Green
W. E. Lay
F. A. Whitten

The Advisory Board on Highway Research of the National Research Council has been active for some time, the object of the board being to center the research facilities of all transport interests on a systematic research program. Much success has been attained in this connection, the organizations represented on the board including all those directly concerned in highway research.

There are many highway problems in which the automotive industry has a vital interest, and some of these cannot be handled adequately without the active assistance of automotive engineers. The effect of vehicles on the road is being investigated by the Bureau of Public Roads and other organizations. The factors in vehicle design, such as weight distribution, springing and tire equipment, are to be studied with the cooperative assistance of automotive engineers. Important items are fuel-consumption, service and depreciation costs as affected by grades and road surfaces. The cost of vehicle operation, including fuel, service and upkeep, is especially important in its relation to cost of highway construction and maintenance. The National Research Council has asked the Society to undertake to develop means for collecting data on the costs of vehicle operation. This information is necessary to establish correctly the economic balance between truck and rail transportation.

Papers at Society Meetings

THE Publication Committee of the Society has called attention recently to certain matters that are of great importance to those who participate in the preparation of and the scheduling of papers for presentation at meetings of the Society and its Sections. The particular point made in this connection is that it is essential that qualitative statements made by authors be supported by quantitative data. Statements made as to the merit of various devices or as to the actuality of alleged facts are, of course, inconclusive unless they are based on authentic test results of a sufficiently comprehensive nature. It is strongly urged that those concerned in the acceptance of papers at Sections Meetings have papers submitted for presentation read in advance by members competent to judge of their merit. Procedure of this kind always tends to bring the best results so far as the time given by members at meetings and the printed record of the Society are concerned.

Financial Affairs

THE net assets of the Society on March 31 amounted to $124,110.89. The corresponding figure on March 31, 1921, was $134,491.61. The difference between the two figures is constituted of the net loss in the operations of the Society during the last 12 months. The net excess of expense over income during the first 6 months of the fiscal year beginning Oct. 1 last was $14,459.60.

The total membership of the Society on March 31 was about the same as on the same day of 1921, those who ceased to be members through non-payment of dues and resignation having offset the number of those newly enrolled. During the first half of the current fiscal year the income of the Society was $13,976.09 less than during the first half of the last fiscal year. Notwithstanding increased expense in the Standards, Research and Employment Service Departments, the total expense of the Society from Oct. 1, 1921, to March 31, 1922, was only a few hundred dollars more than that for the corresponding period of the last fiscal year.

Fuel-Research Program

THE fuel-research program, in which the Society has taken a laboring oar, is making headway, considerable time having been spent recently by the Research Department and officers of the Society on various phases of the whole question.

It is planned that the main research program shall be undertaken shortly at the Bureau of Standards, which has outlined an investigation to estimate the effect of changes in the volatility of gasoline on the average fuel-consumption of the passenger cars now in use. The Na-

(*Concluded on page* 429)

Recent Research Work on the Internal-Combustion Engine

By HARRY R. RICARDO[1]

ANNUAL MEETING PAPER *Illustrated with* CHARTS AND PHOTOGRAPHS

THE author describes the research work on the internal-combustion engine done recently in his laboratory in England, and presents his deductions therefrom, based upon an analysis of the evidence he has obtained to date.

Fuels are discussed at length under three specific headings, many tabular data being included and commented upon, and the calculation of thermal efficiency described. Mean volatility and detonation are discussed and the author's present views regarding turbulence are stated, this being followed by a brief summary of the conclusions reached by Mr. Tizard, a colleague of the author, following recent investigations.

The influence of the nature of the fuel upon detonation is presented, a lengthy discussion of the subject of stratification being given under three specific divisions, inclusive of comment upon the benefits derived from using weak fuel-mixtures. The paper itself is concluded with a discussion of turbulence with reference to combustion-chamber design, many charts and photographs having been included throughout.

The paper is supplemented by nine appendices, which include discussions of mechanical efficiency, under three specific headings; piston experiments, inclusive of four specified deductions; air measurement, with a description of equipment and methods; the total internal energy of the working fluid over a wide range of temperature; the influence of compression-ratio upon power output and efficiency; the influence of cylinder size on performance; the influence of cylinder temperature on power output; the distribution of heat in a high-speed internal-combustion engine; and the efficiency of a single-cylinder engine under reduced loads. This supplementary information is copiously illustrated.

I HAVE read with very great interest the many excellent papers which have been presented to this Society during the last 12 months, and I am deeply impressed by the immense amount of painstaking and careful research that has been carried out in America during this period. Although the experience of the war brought into prominence the great importance of scientific research and gave birth to many schemes and resolutions to encourage and stimulate it, yet the spirit of retrenchment and economy which has pervaded all Europe for the last 18 months has had its inevitable effect and caused the abandonment, or at least the postponement, of many excellent plans. The writer has been singularly fortunate in that, thanks to the encouragement and support of some of the large private British engineering and petroleum interests, he has been able to carry-on with research work through this difficult period and, thanks also to their generous and broad-minded attitude, he is permitted to publish the results obtained.

Last year, Sir Dugald Clerk presented to this Society a paper that I have read with particular interest. In it he has set forth a general summary of the very valuable work he has done. In England, if not throughout the world, Sir Dugald Clerk is very properly regarded as the father of the internal-combustion engine, and I would like to emphasize at the outset that I claim to be no more than a devoted disciple of Sir Dugald Clerk, and to have done no more than to proceed along the lines of research which he has initiated. I also owe a great debt of gratitude to the late Professor Hopkinson both for his teaching and for his stimulating and infectious enthusiasm. To a student of research nothing could be more inspiring than Professor Hopkinson's teaching and personality, for he felt and could impart to others the sheer joy of research work for its own sake; above all, he knew and could teach how to carry out such work quickly, how to separate the grain from the chaff rapidly, and how to reconcile enthusiasm with an open mind.

In the following paper the writer proposes to deal with the work that has been carried out recently at his laboratory, and with the deductions he has drawn therefrom. The deductions are based upon analyses of the evidence he has obtained to date; they represent, therefore, the opinions he holds at the moment and, like all such deductions, are liable to be overthrown or superseded in the light of future work.

FUELS

During the past few years we have been carrying out a good deal of research work on the subject of the influence of different fuels on the performance of an internal-combustion engine. The experiments have all or nearly all been carried out on single-cylinder engines, into which the problems of distribution do not enter. Until, therefore, we have more data on this very intricate subject, I can deal only with the conclusions reached insofar as they are applicable to single-cylinder engines. The three most important factors appear to be the

(1) Tendency of a fuel to detonate
(2) Latent heat of evaporation of the liquid fuel
(3) Mean volatility of the fuel

Broadly speaking, it can be said that all volatile hydrocarbon fuels have the same heat value per cubic inch of mixture giving complete combustion and that, therefore, the power obtainable from all is the same within very close limits when used at the same compression-ratio and at the same volumetric efficiency. The limit of compression-ratio is determined by the tendency of the fuel to detonate; it is a function both of the chemical composition of the fuel and of the maximum flame-temperature. The tendency to detonate by limiting the expansion-ratio controls at once both the power output and the efficiency. The latent heat of evaporation controls the suction temperature, and hence the weight of charge retained in the cylinder; for the same compression-ratio, therefore, the latent heat controls the power output obtainable from any fuel, although the efficiency is, of course, unaffected.

[1] Ricardo & Co., Ltd., London, England.

The mean volatility of the fuel determines the use which can be made of the latent heat of evaporation, for the lower the volatility the more heat must be added externally to the cylinder, and the more the weight of charge will be reduced thereby. It does not appear to be realized generally how important a part the latent heat of evaporation of a liquid fuel plays in the performance of an internal-combustion engine. During the suction stroke of a four-cyle engine, heat is added to the working fluid by

(1) Preheating the carbureter and induction system
(2) Contact with the hot valves and cylinder walls
(3) Admixture with the hot residual exhaust-products in the cylinder clearance-space

Heat is abstracted only by the latent heat of evaporation of the liquid fuel.

For any given aggregate value of (1), (2) and (3), it does not matter whether the fuel is evaporated inside or outside the cylinder, so far as power output is concerned, provided only that the fuel is completely evaporated before the inlet-valve closes. In the former case, the heat applied to the carbureter and induction system will raise the temperature of the air without evaporating the fuel; in the latter, it will evaporate the fuel without raising the temperature of the air. In either case, however, the amount of heat absorbed by the evaporation of the liquid fuel will be the same; and the final suction temperature and therefore the weight of charge retained in the cylinder will also be the same.

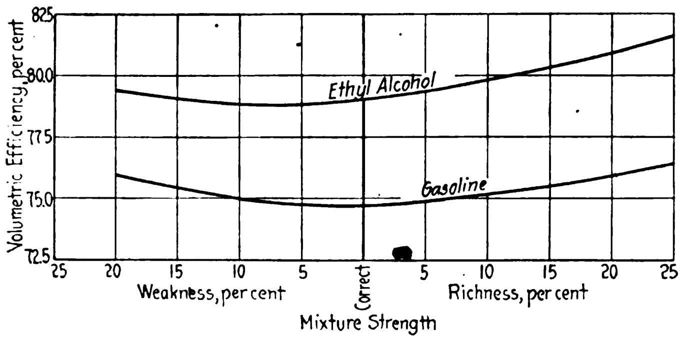


FIG. 1—VOLUMETRIC-EFFICIENCY AND MIXTURE-STRENGTH CURVES FOR A TYPICAL GASOLINE AND NEARLY PURE ETHYL ALCOHOL

So far as pure hydrocarbon fuels are concerned, the latent heat of evaporation is low and does not play a very important part; but, in the case of ethyl alcohol, and still more so in the case of methyl alcohol, the very high power-output obtainable is due almost entirely to the high latent heat of the liquid which is playing an even more important part than is apparent at first sight from a comparison of the mean effective pressure available, because the total internal energy of the alcohols is appreciably lower than in the case of gasoline, benzol and other hydrocarbons.

The curves shown in Fig. 1 give the measured volumetric efficiency at normal temperature and pressure. taken over a wide range of mixture strength with both typical gasoline, (see Fig. 1), and nearly pure ethyl alcohol, each at a compression-ratio of 5 to 1. Table 1 gives the weight of charge per hour, the power output per pound of mixture, the indicated mean effective pressure as found experimentally and the total available internal energy, in the case of three typical fuels, when each is run at the same compression-ratio, with the same amount of preheating and at a mixture-strength giving complete combustion. Column 1 gives the observed weight of charge entering the cylinder per hour at a mixture-strength that permits complete combustion. Column 2 shows the observed indicated horse-power per pound of mixture per hour. Column 3 states the observed indicated mean pressure, at correct-mixture strength, in pounds per square inch. Column 4 presents the calculated heat of combustion of the fuel in terms of foot-pounds per cubic inch at normal temperature and pressure. The engine speed is 1500 r.p.m. and the heat input is 0.0433 B.t.u. per revolution in all cases.

TABLE 1—IDENTICAL TESTS WITH THREE DIFFERENT FUELS

Kind of Fuel	1 Weight of Charge per Cylinder per Hour, lb.	2 Power per Pound of Mixture per Hour, i.hp.	3 Indicated Mean Pressure, lb. per sq. in.	4 Heat of Combustion, ft-lb. per cu. in.
Gasoline	209	0.153	132	48.2
Benzene	212	0.151	132	47.6
99-Per Cent Ethyl Alcohol	224	0.149	138	47.4

It will be seen from Table 1 that, although the power output on ethyl alcohol is greater than on gasoline or on benzene, the power output per pound of charge is actually somewhat lower. I have labored this question of the influence of the latent heat of the fuel upon the power output obtainable because I think it is a very important one in view of the possible use in the near future of certain members of the alcohol group. It does not appear to have been appreciated, nor does the influence of preheating appear to be fully realized. Many designers rely too much on the temperature recorded in the induction-manifold and appear to be under the impression that, so long as the gases are reasonably cool, the power output of an engine is not being penalized; but there can be no greater fallacy. Table 2 gives the indicated mean effective pressure obtained at 1500 r.p.m. from the same group of fuels, with a compression-ratio of 5 to 1, a correct mixture-strength and an engine-room temperature of 15 deg. cent. (59 deg. fahr.). Column 1 is at a constant heat-input of 0.0433 B.t.u. per revolution; Column 2, when preheated to give a temperature in the induction pipe of 25 deg. cent. (77 deg. fahr.); and Column 3, the temperature in the induction pipe with each fuel and with a constant heat-input of 0.0433 B.t.u. per r.p.m. The difference between Columns 1 and 2, in the case of alcohol, is sufficiently striking to need no comment for it will be seen that the effect of raising the temperature from 62 to 77 deg. fahr. results in the case of alcohol in a drop in the mean pressure developed of not less than 19 lb. per sq. in.

TABLE 2—INDICATED MEAN EFFECTIVE PRESSURE AND TEMPERATURE OF INLET GASES

Kind of Fuel	Indicated Mean Effective Pressure 1 lb. per sq. in.	2 lb. per sq. in.	Temperature 3 deg. cent.	deg. fahr.
Gasoline	132	133	26.0	78.80
Benzene	132	128	7.7	45.86
99-Per Cent Ethyl Alcohol	138	119	16.5	61.70

Since the internal energy, and therefore the flame temperature, are substantially the same for all fuels at the same mixture-strength, it follows that the thermal efficiency will be the same. The available range of mixture-strength on the weak side is also substantially the same for all the available volatile liquid fuels; so, in effect, we can say that the thermal efficiency is the same in all cases, with the exception of the members of the alcohol group. These, owing to their lower heat value per gram molecule and higher latent heat, yield a somewhat higher

efficiency because both the compression temperature and the rise of temperature after compression are considerably lower; hence, the direct heat losses and those due to change of specific heat are reduced.

Before proceeding further, I will add a few words as to the method of calculating thermal efficiency. It is generally agreed by engineers and scientists that the useful calorific value of a fuel is its total heat-value less the latent heat of evaporation of the water formed. It is customary, therefore, to reckon the efficiency on the basis of this lower calorific value, and it is legitimate to do so, because the temperature cannot be extended sufficiently in an ordinary cycle to make any use of the heat of condensation of steam.

In determining the heat-value of any liquid fuel in a bomb or other calorimeter, some of the heat of combustion is devoted to overcoming the latent heat of the liquid and is therefore not recorded. In an engine working on the explosion cycle, the entire amount of the heat required to evaporate the liquid is supplied either by the exhaust or by some other source of waste heat; in any event, it is supplied externally to the heat cycle and the actual heat of combustion available is greater than that found by the ordinary methods to the extent of the latent heat of evaporation of the liquid. I contend, therefore, that if it is legitimate to deduct the latent heat of evaporation of the water formed because it cannot be used, in common fairness the latent heat of the fuel should be added to the calorimeter determination because its equivalent value in the heat of combustion can be and is used in the case of explosion, but not of Diesel, engines. If this be accepted, and I am afraid it must be, then all determinations of thermal efficiency must be reduced. In all the work I have published during the last 2 years the thermal efficiency has been calculated on this amended basis.

Some 2 years ago Messrs. Tizard and Pye completed a very thorough investigation into the limiting efficiency obtainable in a gasoline engine, assuming no loss of heat to the cylinder walls but taking fully into account the losses due to increase in specific heat and to dissociation. They traced very carefully the degree of dissociation and recombination throughout the entire combustion and expansion process, and were thus able to arrive at very nearly the true ideal efficiency for any fuel. Their findings, based upon the latest researches in thermo-chemistry, represent probably by far the most accurate information available at the present date. Briefly they show (*a*) that the efficiency obtainable with any hydrocarbon fuel is the same when burnt at the same compression-ratio, within extraordinarily narrow limits; (*b*) that the ideal efficiency for a chemically correct mixture is as given by the equation $E = 1 - (1/r)^{0.258}$; and that, for a mixture strength 20-per cent weak, it is as given by the equation $E = 1 - (1/r)^{0.296}$.

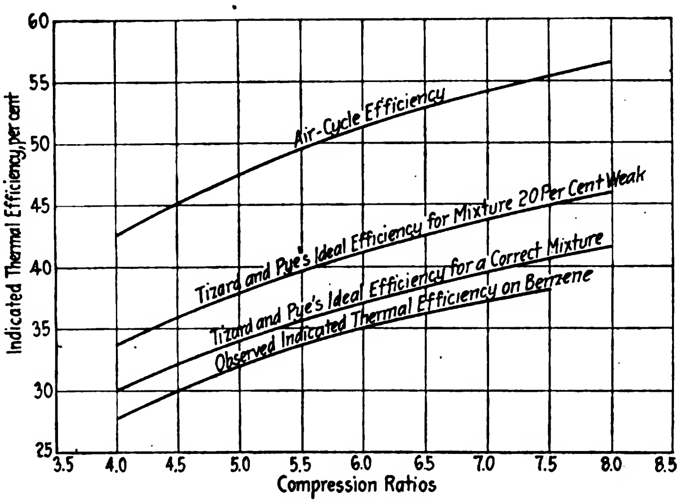


FIG. 2—INDICATED THERMAL EFFICIENCY FOR VARIOUS COMPRESSION-RATIOS

Fig. 2 and Table 3 give Tizard and Pye's ideal thermal efficiencies for a range of compression from 4 to 1 up to 8 to 1; also, the air-standard efficiency and the observed efficiency.

TABLE 3—TIZARD AND PYE'S IDEAL THERMAL EFFICIENCIES

Compression-Ratio	Air-Cycle Efficiency	Tizard and Pye's Correct Mixture	Tizard and Pye Mixtures, 20-Per Cent Weak	Observed Figure for Benzene, 15-Per Cent Weak	Ratio Observed to Tizard and Pye's 20-Per Cent Weak Mixture, per cent	Ratio Observed to Air-Cycle Efficiency, per cent	Ratio of Tizard and Pye's Ideal 20-Per Cent Weak Mixture to Air-Cycle Efficiency, per cent
4 to 1	42.5	30.0	33.6	27.7	82.5	65.3	79.2
4.5 to 1	45.2	32.2	35.9	30.0	83.5	66.3	79.5
5.0 to 1	47.5	34.0	37.8	32.0	84.5	67.2	79.8
5.5 to 1	49.4	35.6	39.6	33.7	85.0	68.1	80.1
6.0 to 1	51.2	37.0	41.1	35.0	85.3	68.5	80.3
6.5 to 1	52.7	38.3	42.4	36.2	85.4	68.9	80.5
7.0 to 1	54.0	39.5	43.7	37.3	85.4	69.0	80.7
7.5 to 1	55.3	40.6	44.9	38.3	85.2	69.1	81.0
8.0 to 1	56.5	41.6	46.0	...	...	...	81.4

It will be seen from Table 3 that both the theoretical and the observed efficiencies rise with an increase of compression at a greater rate than the air-standard, as the latter is increased and the terminal temperature re-

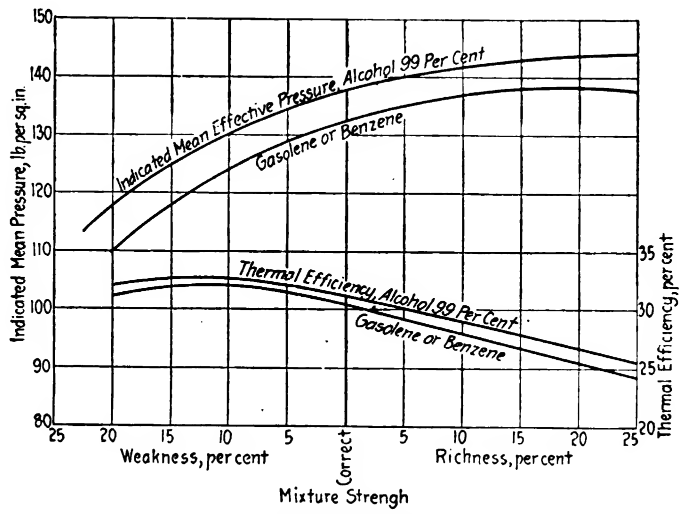


FIG. 3—INDICATED MEAN EFFECTIVE PRESSURE AND THERMAL EFFICIENCY FOR VARIOUS MIXTURE-STRENGTHS OF HEPTANE, BENZENE AND ALCOHOL

duced, due to further recombination during expansion. Tizard and Pye's deductions, as calculated for heptane, benzene and alcohol, cover in effect a wide range of fuels, and the whole available range of mixture-strength for each. For the weakest possible mixture consistent with complete combustion, they have assumed a 20-per cent excess of air. We have been unable to obtain sufficiently rapid or complete combustion with so weak a mixture as this and, in practice, we found that the highest thermal efficiency is always obtained with a 15-per cent excess of air in the case of all the fuels we have examined, except ether and hydrogen.

Fig. 3 shows the observed variation in both mean effective pressure and thermal efficiency over a wide range of mixture-strength for the same three fuels. It will be seen that in each case the maximum thermal efficiency is obtained with a mixture-strength about 15-per cent weak. It will be observed also that, after reaching about a 15-per cent weak mixture, the efficiency falls away due to slow and incomplete combustion. Even with a 15-per cent excess of air, it was found necessary to advance the ignition some 15 deg. earlier, that is, from 32 to 47 deg., than that required for a mixture giving complete combustion. In all these experiments the fuel and air consumption per cycle were recorded automatically and simultaneously, the latter was accomplished by the air-measuring device shown in Figs. 4 and 5. This apparatus is described in Appendix 3.

Mean Volatility

While it would appear that the vapor pressure determines the readiness or tardiness of a fuel to start from a cold condition, it is the mean volatility which decides the amount of preheating required. When considering various fuels, it is desirable to divide them into two groups; those which are homogeneous, such as benzol or alcohol, and those which are heterogeneous, such as gasoline or kerosene. With the homogeneous fuels, comparatively little preheating is required because, although their vapor tension and latent heats may be high, their final boiling-point is low; and, since the object of preheating is primarily to prevent precipitation of the liquid on the walls of the induction system, it is necessary only to raise the temperature of these walls to above the boiling-point of the fuel. When the boiling-point is low, it is possible to raise the whole surface-temperature of the

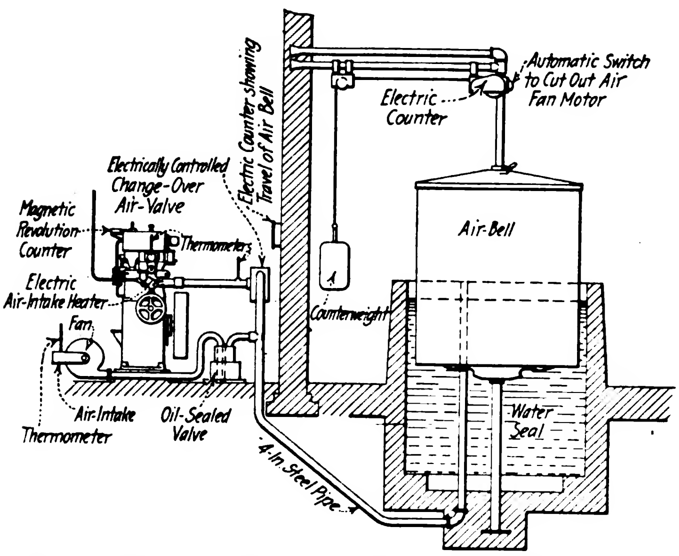


Fig. 4—Diagram Showing the General Arrangement of the Air-Measuring Device

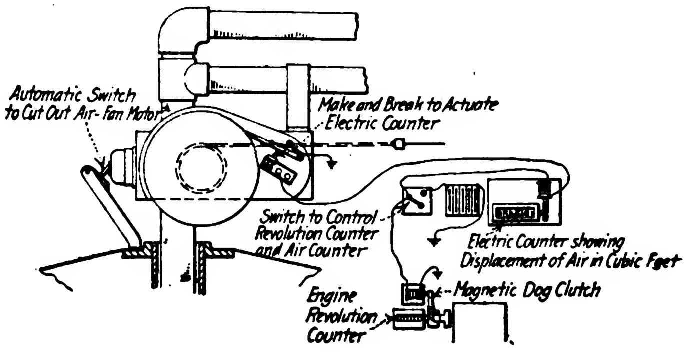


Fig. 5—Electric Counter Used in Connection with the Air-Measuring Device

walls to a sufficient degree without adding much heat to the mixture flowing within.

In the case of fuels having a wide range of boiling-points, such as gasoline, and with a final boiling-point of any value up to 230 deg. cent. (446 deg. fahr.), it is very difficult to prevent precipitation and, at the same time, avoid imparting too much heat to the mixture, for, although the mean volatility of high-boiling-point gasoline and benzol may be, and actually is, nearly the same, the temperature required to prevent precipitation of the heavier fractions is much higher in the case of gasoline, and for the latter only high-temperature heat is of much use. It would appear that in the case of high-boiling-point gasolines it is best to apply a little high-temperature heat just at those points where, owing to changes in velocity or direction in flow, precipitation is most liable to occur, while in the case of the homogeneous fuels low-temperature heat will suffice. There can be no greater mistake than to suppose that, because a fuel's latent heat of evaporation is high and its vapor tension relatively low, it requires excessive preheating.

Vapor tension governs ease of starting but, once started, it probably has very little further influence; thorough pulverization and the avoidance of precipitation then become the most important considerations. This is particularly marked in the case of alcohol which, if properly handled, requires very little preheating; but it does require the most thorough pulverization.

Detonation

The principal factor controlling both the power output and the efficiency of any internal-combustion engine operating on the explosion cycle is the tendency of the fuel to detonate. It is, therefore, not unnatural that so much thought and experimental research have been devoted recently both in the United States and in England to the study of this subject. The phenomenon of detonation appears to be the setting-up in the cylinder of either a true explosion wave or at any rate an extremely rapid rise of pressure. This occurs when the rapidity of combustion of that portion of the working fluid first ignited is such that, by its expansion, it compresses before it the unburnt portion. When the rate of temperature-rise due to compression by the burning portion of the charge exceeds the rate at which it can get rid of its heat by conduction, convection and the like by a certain margin, the remaining portion ignites spontaneously and nearly simultaneously throughout its whole bulk, thus producing a sudden rise of pressure or an explosion wave which actually springs the walls of the cylinder and, reacting in its turn, compresses afresh the portion first ignited. This raises the temperature of that portion further and, with it, the temperature of any isolated or partially in-

sulated objects in its vicinity; thus, it soon gives rise to preignition. Therefore, it would appear fairly certain that detonation depends primarily upon the rate of burning of that portion of the charge first ignited, and it remains to discover what actually controls this rate.

I have always maintained in previous publications that turbulence has an important influence upon the tendency to detonate. This seemed probable, and there was much circumstantial evidence in favor of such an assumption. From more recent investigations, my belief in this has been considerably shaken. I now feel bound to confess that I can find no real evidence that turbulence, while invaluable for other reasons, influences detonation one way or the other. In the case of combustion-chambers designed to give very high turbulence, I found a marked

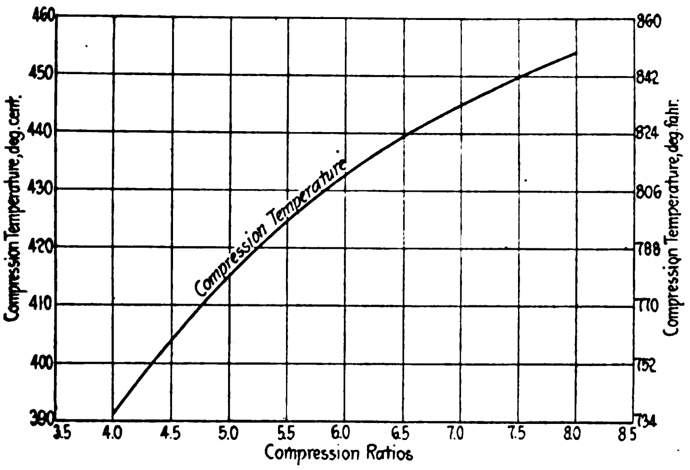


FIG. 6—CURVE SHOWING THE COMPRESSION TEMPERATURE FOR COMPRESSION-RATIOS RANGING FROM 4 TO 1 TO 8 TO 1

reduction in the tendency to detonate, but I am satisfied now that this was due not to the turbulence but rather to the fact that, in each instance, the maximum distance that the flame could travel from the spark-plug was exceptionally small. More recent tests on two engines with multiple valves, in which the turbulence could be varied by cutting out one or more of the inlet-valves, showed that this made no difference whatever as regards detonation.

It was always supposed until recently that detonation is dependent upon the temperature of compression; this appeared plausible enough at first sight, but it most certainly did not fit in with the observed facts. For example, the difference in compression temperature between a compression-ratio of 4 to 1 and 6 to 1 is actually only about 40 deg. cent. (72 deg. fahr.), and this difference can easily be more than counterbalanced by a change in the amount of preheating of the charge; but, we all know from experience that, while detonation on say a reasonably good gasoline will not occur with considerable preheating at a compression-ratio of 4 to 1, it will inevitably occur far below a compression-ratio of 6 to 1 without any preheating at all, and even with stone-cold cylinder-jackets. The curve in Fig. 6 shows to the nearest approximation the compression temperature for a range of compression-ratios from 4 to 1 to 8 to 1, assuming (*a*) the same amount of preheating and the same latent heat in every case, and (*b*) allowing for the varying proportion and temperature of the residual products at each compression-ratio.

Our experiments appeared to show pretty clearly that detonation has very little connection with the temperature of compression, but is closely dependent upon the

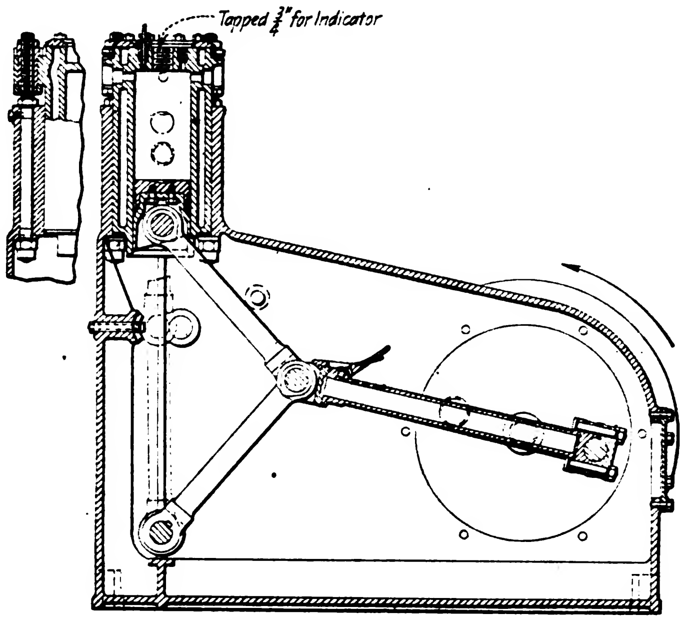


FIG. 7—SECTIONAL ELEVATION OF A MACHINE DEVELOPED BY THE AUTHOR FOR IGNITING FUEL-AIR MIXTURES BY ADIABATIC COMPRESSION

compression pressure. Therefore, I concluded that it is the pressure rather than the temperature of the working fluid which controls the initial rate of burning, and therefore the tendency to detonate. This seemed reasonable. It fitted in nicely with the facts of the case and did duty for a while as an explanation until the chemists objected on the ground that the rate at which combustion takes place under these conditions is generally influenced but little by such relatively small differences of pressure. It then became necessary to cast about for another explanation, and to find one that would satisfy the chemists also.

For the purpose of such an investigation we designed and built a machine for igniting fuel-air mixtures by adiabatic compression alone, and in which either the compression-ratio or the temperature could be varied at will over a wide range. A sectional drawing of this machine is shown in Fig. 7. In this apparatus the piston is operated by a toggle mechanism in such a manner that it makes one rapid stroke and then remains locked at the top dead-center. By varying either the compression-ratio or the temperature of the charge within the cylinder, a condition could soon be found under which any fuel-air mixture would just self-ignite. It was found with this machine that, for every specific fuel and for any mixture-strength of that fuel with air, there

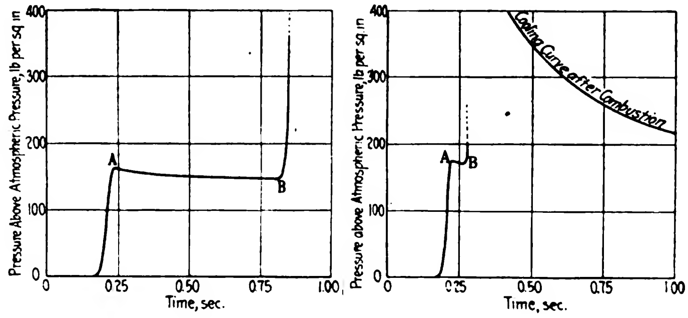


FIG. 8—TWO TYPICAL INDICATOR-DIAGRAMS OF A HEPTANE-AIR MIXTURE OBTAINED WITH THE FUEL SELF-IGNITION MACHINE SHOWN IN FIG. 7

Reading from Left to Right the Maximum Compression Temperatures Were 282 Deg. Cent. (540 Deg. Fahr.) and 307 Deg. Cent. (585 Deg. Fahr.)

was a fairly definite temperature at which self-ignition occurred. This self-ignition took several forms; for example, at x minus 15 deg. cent. (27 deg. fahr.) the mixture would start to burn immediately on the completion of the compression, but would burn so slowly that the pressure would actually fall slightly. Such burning would often continue for nearly 1 sec., the rate of heat supply not wholly balancing the rate of heat loss. At, say, x deg. the same phenomenon would be observed at first, but with the difference that the pressure would fall slightly for the first 0.25 sec.; it would then rush up almost instantaneously to a maximum at which combustion would be complete.

This is shown in the typical diagrams given in Fig. 8. If the temperature were raised a further degree or two, the interval of slow burning at nearly constant pressure would be reduced to perhaps 0.10 sec. Thus, between the most timid and hesitating, and the most prompt and decisive burning, there would be found in each case a range of temperature of perhaps about 30 deg. cent. (54 deg. fahr.); but, since it was possible to vary the compression temperature within fine limits, this range could be explored very thoroughly. It was most extraordinarily consistent and, for any given mixture-strength or any given fuel, one could adjust the machine beforehand with the certainty that one could obtain a 0.10, 0.20, or even a 1.00-sec. interval between the commencement of combustion and the sudden pressure-rise. These first tests were all run with a stagnant charge; later a fan was fitted inside the cylinder and driven at a speed of about 2500 r.p.m. by a small electric motor. With the fan revolving, precisely the same phenomena were observed, but at a slightly higher compression temperature which merely balanced the increased rate of heat loss; the intervals between the commencement of burning and the sudden pressure-rise, although relatively the same, were much smaller in all cases. In short, the fan speeded up the whole process; but it did not alter perceptibly its character.

These investigations have been carried out very recently at our laboratory by Tizard. Since he has not yet had time to prepare his work for publication, it would not be fair for me to enlarge upon it; but he has made public some of the conclusions arrived at, and they have been so amply confirmed, not only by tests on our own research engines but also by their close agreement with general experience, that there seems to be little doubt as to their correctness. Briefly, Tizard's conclusions are that, for any given fuel

(1) Detonation depends primarily upon the rate of burning of that portion of the charge first ignited; in this he confirms the usually accepted theory
(2) The rate of burning increases very rapidly with a slight increase of the flame-temperature; and whether it will prove sufficiently rapid to produce detonation, depends upon the ratio between the rate of evolution of heat by the burning portion of the mixture and the rate of heat loss
(3) The chance that the rate of burning of any portion of the mixture will become so high as to cause detonation depends but little, so far as the practical engine conditions are concerned, upon the temperature or pressure of compression, but rather upon the maximum flame-temperature
(4) For any given mixture-strength, the maximum flame-temperature depends primarily upon the proportion of diluent or exhaust products present. It depends also, of course, upon the compression temperature; but this varies comparatively little over a wide range of compression-ratio, while the variation in the proportion of residual exhaust-products over the same range exerts a much greater influence in diluting and so lowering the temperature of the flame. Thus, a difference of ± 1 per cent by weight of exhaust diluent will raise or lower the flame-temperature by about 25 deg. cent. (45 deg. fahr.), which is equivalent to a range of compression from 4 to 1 to 5 to 1
(5) If the flame-temperature be reduced by weakening the mixture-strength, a very much higher compression could be used at once. In practice, with the exception of hydrogen, it is not possible to weaken the mixture so as to effect any large reduction in the flame-temperature because, within the narrow range available, weakening the mixture with air results merely in reducing the amount of dissociation without affecting appreciably the flame-temperature

Fig. 9 shows the observed variation in compression-ratio permissible over a wide range of mixture strength. In this experiment the engine was run with wide-open throttle at constant speed and constant temperature, and the compression-ratio was adjusted at each mixture-strength until detonation just became apparent. With both hydrogen as a homogeneous charge and with a stratified charge of aromatic free gasoline, it was found possible to operate at a compression-ratio of about 7 to 1 with a mean mixture-strength 50 per cent weak, and without the least trace of detonation. Fig. 10 shows a similar test with hydrogen, but with the mixture-strength much further reduced, as is possible only with this fuel. On the other hand, with hydrogen the range of burning on the rich side could not be explored because, as soon as any excess of hydrogen was admitted, backfiring occurred through the inlet-valves.

It will be seen that the new theory, although based on much sounder reasoning, squares on the whole with my older theory; and that, in the case of a normal homogeneous mixture, the tendency to detonate depends, in effect, upon the compression pressure, not, as I supposed, because the pressure has any marked influence, but rather because, in any actual engine, the compression pressure is, in itself, a measure of the proportion of inert diluent present in the cylinder. It differs in practice only when, by the use of hydrogen, by stratifying the charge or by the introduction of inert diluents, a weak mean mixture-strength can be used. Tizard's theory has been further confirmed by other tests that we have run, in which

(1) The residual exhaust-products have been cleared away by scavenging with air; it was found then that detonation became severe at once, even with very low compression-pressures
(2) Additional exhaust-products were added, by way of the carbureter; the compression could be raised then to almost any degree, depending upon the quantity admitted

Fig. 11 shows the variation in compression-ratio permissible when, to a gasoline detonating normally at a compression-ratio of 4.85 to 1, varying quantities of additional exhaust-products were added and the compression adjusted in each case until detonation just became apparent. Other tests using nitrogen, steam and carbon dioxide have given similar results. The effectiveness of such inert gases appears to be closely proportional to their specific heats; that is, to their direct influence upon the flame temperature.

Broadly speaking, it would appear from our experiments that two factors determine whether or not a fuel

will detonate. These are (*a*) the self-ignition temperature of the fuel-air mixture and (*b*) the rate of acceleration of burning as the ignition temperature is exceeded.

Both the true self-ignition temperature, if indeed such a term can be used, and the rate of acceleration of burning appear to depend primarily upon the chemical composition of the fuel. As a broad generalization, our experiments confirmed that, as regards groups, the paraffins are the worst offenders from the viewpoint of detonation, the naphthenes are better, the olefins better still, the aromatics next and the alcohols the best of all. This, however, can be regarded only as a very broad generalization, because the individual members of the various groups behave very inconsistently among themselves. Thus, pure pentane will withstand a compression-ratio of 5.85 to 1 and is, in fact, comparable with a naphthene. Pure hexane detonates at a compression-ratio of 5.1 to 1, but pure heptane will barely withstand even a 3.75 to 1 ratio, which is the lowest compression we could reach. The behavior of heptane is particularly striking. The first samples used were obtained from California, from

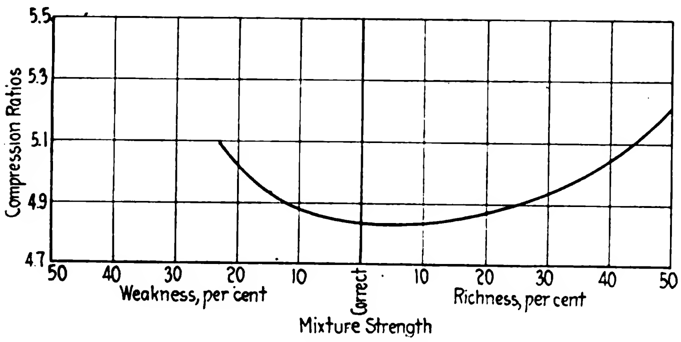


FIG. 9—CURVE SHOWING THE COMPRESSION-RATIO AT WHICH THE DETONATION-POINT BECOMES APPARENT WITH VARYING MIXTURE-STRENGTHS OF AROMATIC FREE GASOLINE AND AIR

a vegetable source; and, although on investigation they were found to be pure samples of normal heptane and not isomeric forms, we still felt some doubt. Later, and with great difficulty, some small quantities of heptane were isolated from aircraft gasoline. Later still, some further supplies were obtained from Germany from Galician oil. Both these later samples gave exactly the same results. It will be seen, therefore, that, while the average of these three members of the paraffin series agrees reasonably closely with the results obtained from a nearly pure light paraffin gasoline, the individual effects appear to be widely different. This difference was not, however, observed when the same three members of the paraffin series were examined in the compression apparatus when their behavior appeared normal. A similar inconsistency was observed in the engine tests in the case of the aromatic series when toluene was found to be markedly superior to xylene and xylene to benzene.

With regard to the rate of acceleration of burning, the case of carbon bisulphide provides a very interesting example. This fuel has a very low ignition-point and will preignite readily at a very low compression-ratio but when added to gasoline it serves as an effective anti-detonator and will actually permit a considerable increase in compression. When investigating in the machine Tizard found that, while the rate of burning of most liquid fuels, about the region of their self-ignition temperature, trebles for every 4-per cent increase in temperature, carbon bisulphide required a rise of temperature of 7 per cent to treble its rate of burning. The

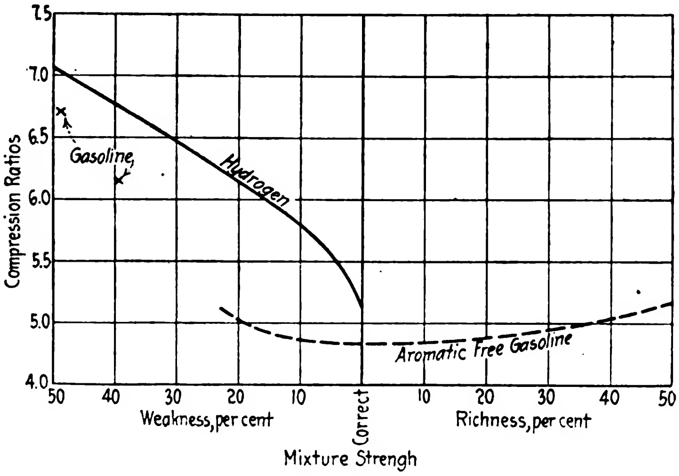


FIG. 10—COMPRESSION-RATIO AT WHICH THE DETONATION-POINT BECOMES APPARENT WITH VARYING MIXTURE-STRENGTHS OF HYDROGEN AND AROMATIC FREE GASOLINE AS WELL AS TWO POINTS OBTAINED WITH A STRATIFIED CHARGE OF AROMATIC FREE GASOLINE

majority of the experiments on which the above conclusions are based were carried out on our 4½ x 8-in. variable-compression research-engine shown in Figs. 12 and 13.

STRATIFICATION

Careful analysis of the behavior of the working fluid in an internal-combustion-engine cylinder shows that under ordinary circumstances we must not look for an efficiency relative to the air cycle of more than about 70 per cent., at ordinary compression-ratios. The principal sources of loss are

(1) Increase of specific heat at high temperatures
(2) Dissociation with incomplete recombination during expansion
(3) Direct loss of heat to the cylinder walls

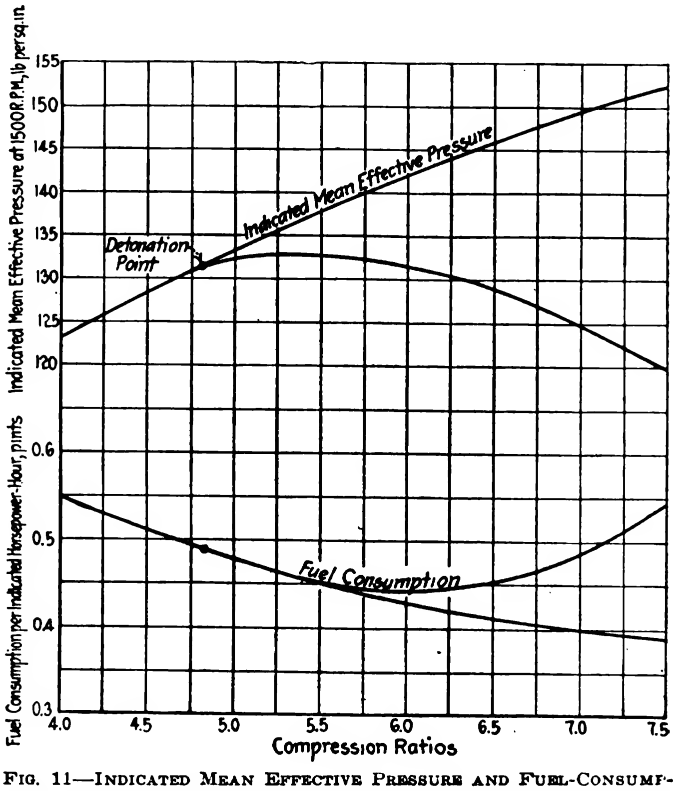


FIG. 11—INDICATED MEAN EFFECTIVE PRESSURE AND FUEL-CONSUMPTION CURVES OBTAINED BY ADDING VARYING QUANTITIES OF ADDITIONAL EXHAUST-PRODUCTS

These amount collectively to an absolute minimum of 30 per cent. In practice they generally approach nearer to 40 per cent.

Each and all of these sources of loss are directly dependent upon the flame-temperature, and more particularly the flame-temperature during combustion, for we must be careful to distinguish between loss of heat during combustion and that lost during expansion. If the loss of heat during the combustion period and before expansion could be suppressed, the heat recovered could be utilized at an efficiency corresponding to that of the whole expansion, or, say, about 40 per cent. A similar amount of heat lost, say, one-half way down the expansion stroke, could have been used only at an efficiency corresponding to that due to the latter half of the expansion; but heat lost toward the end of the expansion stroke is of very little consequence. Perhaps this is rather a digression, but it is customary to refer to the heat lost during combustion and expansion without discriminating between the two.

With any volatile liquid fuel and, with the exception of hydrogen, with such gases as we have examined, the range of burning on the weak side is so narrow that the maximum flame-temperature cannot be reduced to any appreciable extent. Any attempt to do this with a homogeneous mixture results merely in slow and incomplete combustion. Flame lingers in the cylinder, and the fresh charge is ignited on entry. This sets a definite limit to the range that can be used on the weak side, but the practical limit is reached before this when, owing to delayed and incomplete combustion, the thermal efficiency falls off as the mixture-strength is reduced. Fig. 3 shows the variation in thermal efficiency with mixture-strength, over a wide range. Within exceedingly narrow limits, these relations can be said to hold good for any volatile liquid fuel we have ever encountered. It is indeed very

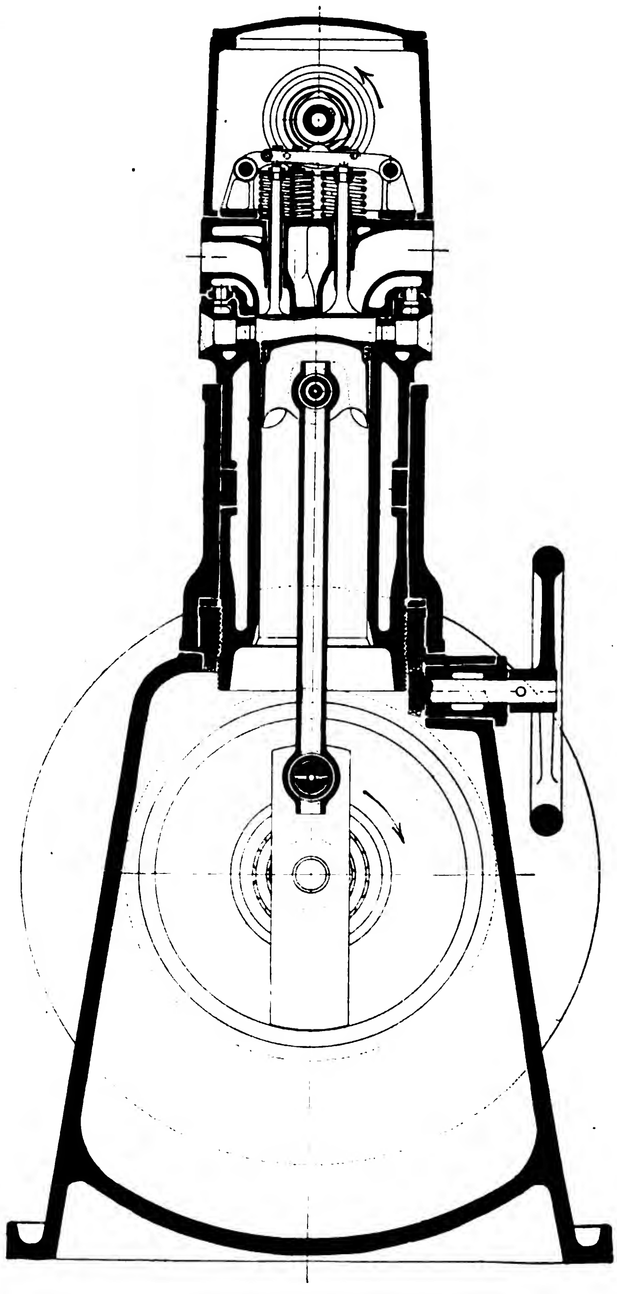


FIG. 12—SECTIONAL ELEVATIONS OF THE 4½ X 3-IN. VARIABLE-COMPRESSION RESEARCH ENGINE UPON WHICH THE MAJORITY OF THE EXPERIMENTS WERE MADE

experimentally, and in approaching reasonably nearly the results which theory would lead one to expect. In fact,

FIG. 15—SECTIONAL ELEVATION OF THE CYLINDER-HEAD OF THE STRATIFIED CHARGE ENGINE

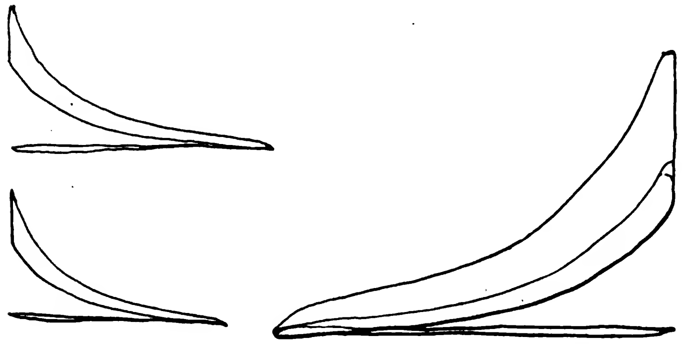


FIG. 16—THREE INDICATOR-CARDS OBTAINED WITH THE STRATIFIED-CHARGE ENGINE

air-valve opens there is a considerable depression in the cylinder, and it is probable that any rich mixture that has overflowed from the pocket retires back into it when the depression is relieved. On the compression stroke, the contents of the cylinder are compressed and some air is driven into the bulb, creating great turbulence therein. The mixture in the bulb is fired at the end of compression and, owing to the turbulence, it burns with extraordinary rapidity. The flaming mixture then rushes out through the narrow neck where it meets and immediately mixes with a very large excess of air; thus, by igniting a small proportion of rich mixture in the first place, I succeeded, in effect, in igniting a large volume of very weak mean-mixture-strength. The power output of this engine could be varied, either by the quantity of fuel alone, or by varying the proportion of mixture of nearly constant strength admitted to the bulb.

With either method of control, the engine would run at any load from dead light to an indicated mean effective pressure of about 120 lb. per sq. in.; but, to obtain the best thermal efficiency throughout so wide a range, it was found necessary to combine both methods. All this seemed beautifully simple and wonderfully effective, and the running of the engine on the light loads was almost exactly like that of a steam engine in its smoothness and sweetness generally. The experimental engine had a water-cooled bulb; but it had no water-jacket or fins on the cylinder and, although of 5-in. bore, it would run continuously at an average mean effective pressure of about 20 lb. per sq. in. without blistering the paint on the cylinder walls, while the exhaust, although perfectly free, sounded almost like deep breathing. In Fig. 16 a number of indicator diagrams taken from this engine are shown.

Fig. 17 shows the thermal efficiency obtained from it

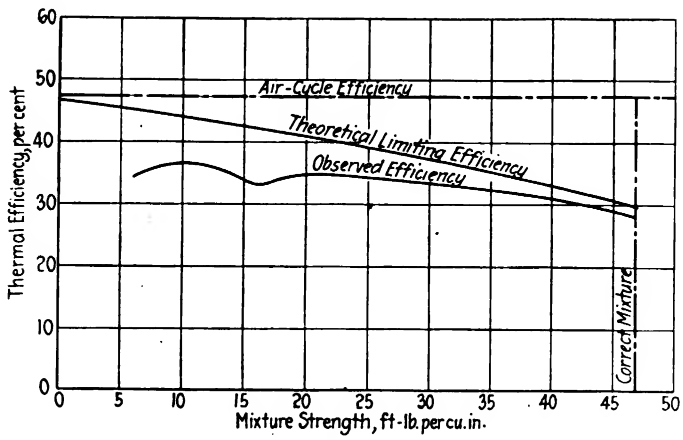


FIG. 17—EFFICIENCY-MIXTURE-STRENGTH CURVES OBTAINED FROM THE TESTS ON THIS ENGINE

with a compression-ratio of 4.8 to 1 and when running at a speed of 600 r.p.m. So far, everything seemed satisfactory and, indeed, so far as this one engine was concerned, it certainly was satisfactory, the only defect being that, do what I would, I could not avoid a small zone of relatively low efficiency over some part of the range. I could vary the position of that zone up and down the range, but I could not eliminate it. Next, I tried the experiment of fitting similar bulbs to several engines with different types of combustion-head, merely substituting the bulb in place of the spark-plug. This proved a disastrous failure in every case. At certain loads, generally at about one-quarter load, I could obtain a very high efficiency indeed; but this was counterbalanced by a miserably low efficiency and irregular running at other loads and, in most cases, I failed utterly to carry more than from one-half to two-thirds the load of which the engine was ordinarily capable. Subsequent experience showed that everything depended upon the

(1) Shape of the combustion-chamber below the pocket
(2) Shape and size of the neck connecting the pocket with the combustion-chamber
(3) Position of the spark-plug in the bulb

The dependence upon (3) is remarkable, in view of the excessive turbulence set up in the bulb; but it has proved very sensitive, none the less. During the war I was forced to discontinue experiments along these lines, but I was able to devote much time to experimenting with a supercharging engine in which I made use of stratification to a limited extent. After many initial difficulties, this eventually proved to be very satisfactory. Since the war I have had little opportunity to return to these experiments. However, some 2 years ago, I did convert one of the two high-speed gas-engines supplying power to the laboratory, to run with a stratified charge, but I was careful to fit a cylinder-head and bulb exactly similar to that which I used on the first engine. This has proved to be entirely successful after about 20 months of continuous running. The engine runs in parallel with a sister engine similar in every other respect, but operating with a homogeneous mixture and throttle-governed. There is no comparison between the two in general behavior.

Fig. 18 shows a sectional drawing and an elevation of this gas engine. On the other hand, the engine using a homogeneous charge requires a top overhaul and the exhaust-valve reseated every 2 months. The engine using a stratified charge has had its cylinder-head removed only once in 20 months. The exhaust-valve then was found to be in excellent condition. There was no carbon on the piston, there being only a little coating of thick oil of the consistency of tar that could be wiped off with a rag, thus leaving the piston clean and bright. When running in parallel on a fluctuating load, but with an average load-factor of about 50 to 60 per cent, the governing on the gas supply alone has proved perfectly satisfactory. The only defect is that, while its sister engine will develop a maximum brake mean effective pressure of 110 lb. per sq. in., the engine using a stratified charge will not do more than about 80 lb. per sq. in., showing that it has not the overload capacity of its sister engine. Incidentally, it is interesting to note that this engine will run also without a trace of detonation on aromatic free gasoline up to a mean effective pressure of about 80 lb. per sq. in., despite the fact that its compression-ratio is 6.5 to 1, thus supplying additional evidence in favor of Tizard's theory about detonation.

As a result of these experiences, the writer believes there is little doubt that, sooner or later, the system of working with a stratified charge will become commercial, for, as he has shown, it is possible and the high efficiency theoretically obtainable from it can be approached. The worst feature about it is that, if not just right, it may be very wrong; a very small change in form or dimension may upset the whole system. In such a case the thermal efficiency may very easily be much worse than that of a throttle-governed engine. It will not be a commercial proposition, he fears, until the influence of each of the variable factors has been determined separately and evaluated correctly.

Turbulence and Combustion-Chamber Design

The great value of turbulence lies, in my opinion, in the

(1) Speeding-up of the process of combustion by the mechanical distribution of flame

(2) Scouring effect it produces in washing away the stagnant layer of gas adhering to the cylinder walls

It appears now to be clearly established that the normal rate of burning of a fuel-air mixture is, at the start, far too slow to be of any value; although, as shown by our experiments on the adiabatic-compression machine, its acceleration after a certain stage is extremely rapid. It is probably in speeding-up the initial stages of combustion by spreading mechanically the pale and timid flame brought into life by the spark-plug, that turbulence plays its most important part, and this becomes most conspicuous when operating with weak mixtures.

Again, there is a good deal of presumptive evidence to show, that, in any combustion-chamber, there is always a layer of gas adhering to the walls of the chamber which, owing to its proximity to these walls, can get rid of its heat so rapidly that it does not burn completely. The effective thickness of this layer depends very largely, no doubt, upon the degree of turbulence. It appears to be this factor rather than the greater direct heat-loss which renders certain forms of combustion-chamber commonly used with side-valve engines so inefficient. There is much to be said in support of this theory, because it will help to explain the very marked difference in efficiency and power as between a high and a low degree of turbulence in the same combustion-chamber, even when using relatively rich and prompt-burning mixtures and firing from two points. Also, while the efficiency obtainable from two forms of combustion-chamber of much the same surface-area may be very different, the heat loss to the cooling water is generally much the same in both cases, showing that it is in the proportion of heat rejected to the exhaust that the difference in efficiency appears to lie rather than in that lost to the cylinder walls.

In his excellent paper on Turbulence,[3] H. L. Horning refers to and illustrates a form of combustion-chamber

[3] See The Journal, June, 1921, pp. 584 and 585.

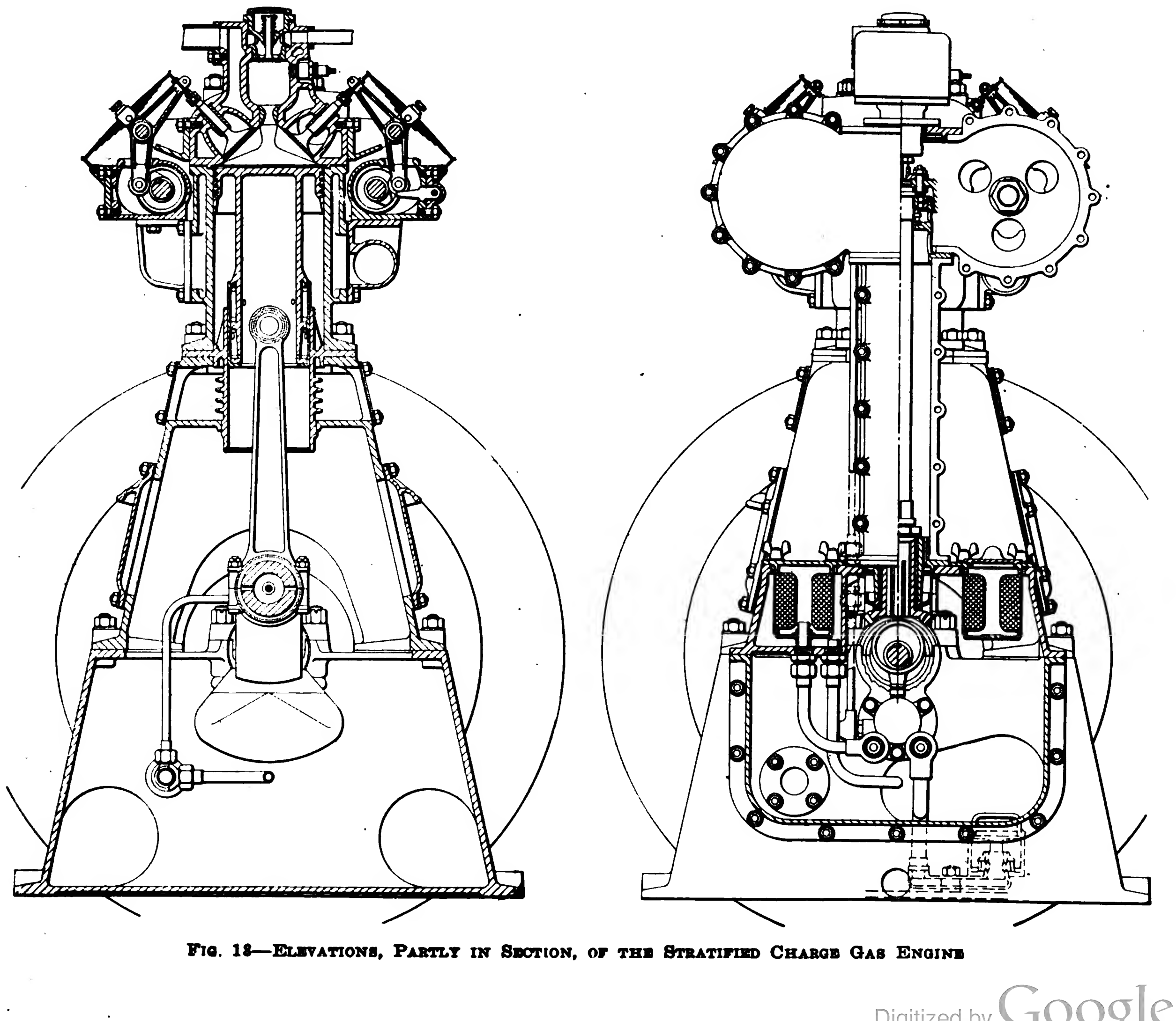


Fig. 18—Elevations, Partly in Section, of the Stratified Charge Gas Engine

FIG. 19—EXTERIOR OF THE 225-HP. RICARDO TANK-ENGINE

that we have used in the small engines we designed for Mark Webber, in England, and also in all the standard 150-hp. tank-engines. It is shown in Fig. 11 of Mr. Horning's paper and he remarks that, in his experience, this form of chamber with the spark-plug over the piston is unsatisfactory from the viewpoint of detonation. I can endorse this statement fully. We have found this form of combustion-chamber remarkably efficient from the viewpoint of power output and efficiency, for, with a compression-ratio of only 4.3 to 1 we were able to obtain, both in the Mark Webber and in the tank engines, a brake mean effective pressure of 108 lb. per sq. in. and a fuel-consumption of only 0.55 lb. of gasoline per b.hp-hr. in the Mark Webber single-cylinder and of 0.57 in the six-cylinder tank-engines. But we always found it bad from the standpoint of detonation; so bad that in the larger and later tank engines we decided very reluctantly to abandon it in favor of a much more compact form using horizontal valves, and with the spark-plug in the center, as shown in Figs. 19 and 20. This gave about equal results as regards efficiency and mean effective pressure, but was remarkable as regards its freedom from detonation; in fact, these large engines would run comfortably even on kerosene with a compression-ratio of 4.3 to 1 and without any cooled exhaust-products.

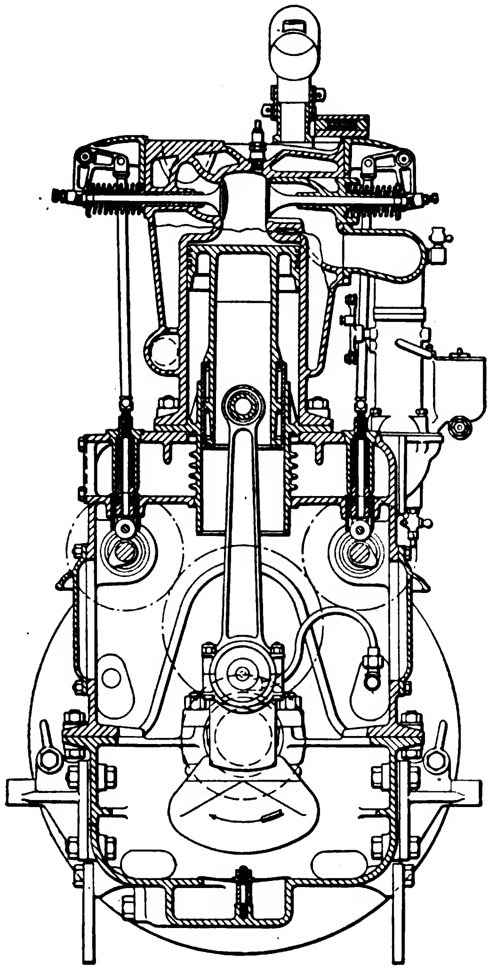


FIG. 20—END ELEVATION, PARTLY IN SECTION, OF THE 225-HP. RICARDO TANK-ENGINE

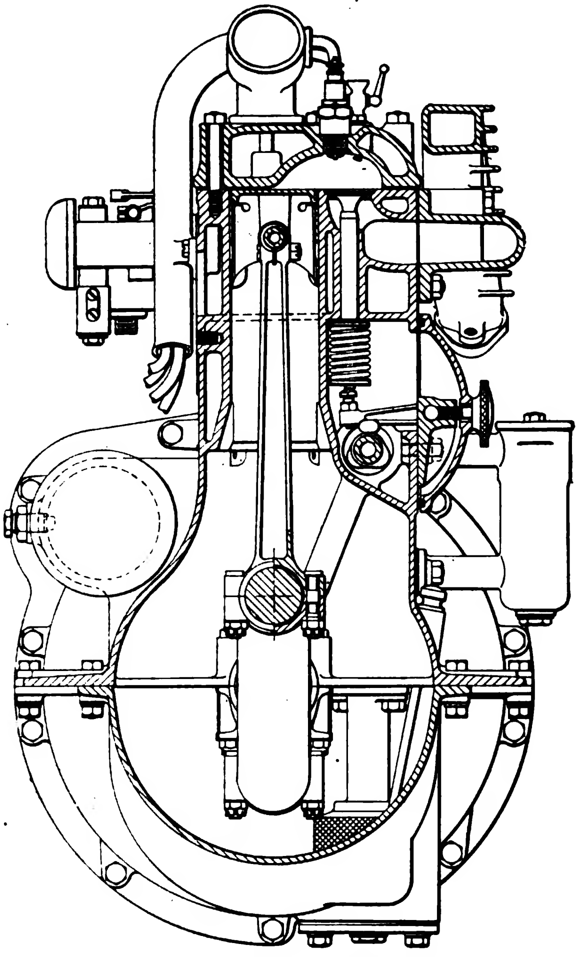


FIG. 21—ELEVATION, PARTLY IN SECTION, OF A 11.9-HP. ENGINE

The Form of Cylinder-Head Shown Was Adopted for All Side-Valve Engines Since It Produced Additional Turbulence during the Compression Stroke and Also the Minimum Distance from the Point of Ignition to the Farthest Point in the Combustion-Chamber

Later, we adopted the form of head shown in Fig. 21 for all side-valve engines. This has proved the best of all we have tried for side-valve engines, for it produces additional turbulence during the compression stroke and, moreover, the maximum distance from the point of ignition to the farthest point in the combustion-chamber, the factor which apparently controls detonation beyond all others, is about the smallest possible. It appears to combine the virtues of both the forms of combustion-chamber we used in the tank engines.

Table 4 shows the results of tests of a fairly large number of engines, most of them of our own design. The figures are not in all cases truly comparative but they probably approach a true comparison as nearly as

TABLE 4.—RESULTS OF TESTS ON VARIOUS TYPES OF ENGINE

any that can be obtained, short of taking an experimental cylinder and grafting different combustion-chambers and valve-gears upon it, which would be no easy problem. In all cases marked with an asterisk the valve-opening diagram is the same and so is the gas velocity throughout the induction system, because we have arrived at a more or less standard timing and valve-opening diagram for all of our engines. Also, in all cases an engine speed has been chosen corresponding to a mean velocity through the valves of from 130 to 150 ft. per sec.

From this we may presume that the volumetric efficiency is substantially the same in all cases. The fuel used for the tests is Borneo gasoline in each instance but, unfortunately, the heat-input to the carbureter could not be measured in most cases, and introduces an indeterminate variable. The figures in column 12 represent, to the nearest approximation, the true figure of merit for the particular combustion-chamber. As regards columns 13 and 14, it must be borne in mind that, except in the case of single-cylinder engines, irregularities in distribution may easily more than outweigh any differences due to combustion-chamber design, as discussed in Appendix 3.

Since, within very close limits, the volumetric efficiency can be presumed to be the same in all cases marked with an asterisk, column 2 gives the nearest approach to the true comparative efficiency of the different forms of combustion-chamber, but it is necessary to remember that valves which open directly into the cylinder-head have a somewhat higher orifice-coefficient than those which open into side pockets and that, in consequence, the volumetric efficiency will be somewhat higher in the case of the overhead-valve engine, although, in all cases, ample area was provided around the valve-heads. It will be seen from Table 4 that the overhead-valve engines, whether of plain cylindrical form or of the pent-roof type, appear each to be about equally good.

The type described as an L-head, with a modified valve arrangement in which the inlet is located over the exhaust, appears to come next in order of merit, while those fitted with the design of combustion-chamber shown in Fig. 21, apparently come third. It must be noted, however, that the so-called L-head combustion-chamber is very bad from the viewpoint of detonation, so that it necessitates the use of a lower compression-ratio than that employed in the next group. It will be found that the order of merit is reversed when this is taken into account. The remarks as to the tendency to detonate must be understood to refer to this tendency relative to the compression-ratio employed.

In conclusion, I wish to express my thanks to all the members of my staff for their whole-hearted cooperation and assistance.

Fig. 22—View of the Piston-Testing Apparatus Employed by the Author

APPENDIX 1

Mechanical Efficiency

In previous papers, I have given both the results of my experiments on mechanical efficiency and the deductions drawn therefrom. These can be summarized generally by stating that piston friction accounts always for more than one-half of the total mechanical losses and in many cases for nearly three-fourths. It appears to be controlled by three factors,

(1) Area of rubbing surface
(2) Average pressure between the surfaces; in high-speed engines this is due largely to the resolved component of the inertia forces
(3) Condition of the lubrication

The means of dealing with the first two factors are obvious; namely a reduction of the surface and weight. Fortunately, a reduction in the weight results in a reduction also in the pressure on the surfaces due to inertia, and so renders smaller bearing surfaces permissible. The partial carbonizing and congealing of the lubricating oil is more difficult to deal with, for, toward the end of the expansion stroke, a very large proportion of the surface of the barrel, and of the oil adhering to it, is exposed to flame at a temperature of about 2000 deg. cent. (3632 deg. fahr.), and it is by no means easy to see how this can be prevented.

In all of our tests for determining mechanical efficiency by "motoring," which consists in driving the engine by the motor used for the dynamometer and measuring the power required electrically, we find that if the ignition is switched off and the engine turned over to motoring, immediately after running on full load, the total friction is at first rather high but gradually drops until, after a period of say 15 min., it has fallen at least 10 per cent and often as much as 20 per cent due, presumably, to the gradual change from fouled to clean oil on the cylinder walls, and this without any change in temperature.

Although skeptical at first, I have lately come to the

conclusion that the motoring test, if carefully carried out under conditions approaching as nearly as possible the actual running conditions, in most cases gives a surprisingly accurate measurement of the true friction-losses, despite the fact that many conditions are changed. It should be taken into account that, when motoring, the fluid pumping losses are, on an average, some 50 per cent higher than when running normally because (*a*) the exhaust back-pressure is much greater owing to the fact that there is no high pressure at the time of discharge to supply the kinetic energy necessary to propel the exhaust products down the exhaust-pipe, and (*b*) there is a loss of heat during the compression-stroke which is not fully recovered during expansion, with the result that there is a negative loop to the compression-expansion card.

This increase in fluid pumping losses, however, nearly balances, on an average, the decrease in piston friction when motoring and this appears to be true over a wide range of speed. Another method, which we always use as a check-test for mechanical losses in multi-cylinder engines, is to run the engine "all-out" with all cylinders firing until all conditions have steadied down; then short-circuit the ignition of one cylinder at a time, recording accurately the power developed in each case by the remaining cylinders. The difference observed is the indicated horsepower of the cylinder which is out of operation. This method almost invariably gives rather too low a figure for the total losses. We have employed another method on our variable-compression engine, which has a very heavy flywheel and a built-up crankshaft mounted on ball bearings. We remove the crankpin and motor the flywheel up to say 2000 r.p.m.; then we switch off the dynamometer and note the deceleration. The crankpin is then replaced and the engine is run under full load at 2000 r.p.m., switched off and the deceleration noted again. From the difference so observed, the total mechanical losses can be estimated over the whole range of speed from 2000 r.p.m. down to zero, or from full speed to stoppage of the engine.

In an engine such as my variable-compression unit, which has been in constant use for over 2 years, running daily under close observation, the true mechanical efficiency can be determined by various processes of elimination and by all sorts of cross-checks. All of these methods confirm the fact that the true mechanical efficiency agrees extremely closely with that shown by the motoring test previously described.

APPENDIX 2

Piston Experiments

A great many experiments have been carried out on a special piston-testing machine, shown in Figs. 22, 23 and 24, that consists of a water-jacketed cylinder in which a piston is reciprocated by a swinging-field electric dynamometer. The cylinder is heat-insulated from the crank-case, and the jacket is filled with water that is stirred constantly by a small propeller fitted therein. The machine is, in effect, a calorimeter, and the piston friction, wholly apart from all other sources of friction, can be measured in relative terms by the temperature rise of the jacket water. It is very difficult to obtain reliable absolute figures in this way, because the radiation losses play so important a part, but the relative figures so obtained

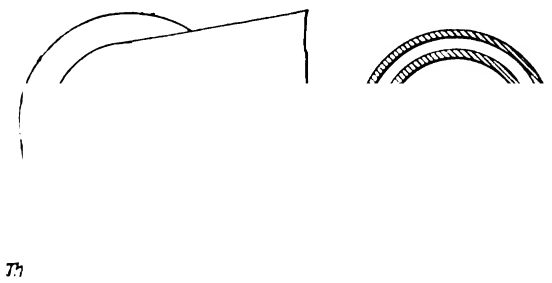


Fig. 23—Longitudinal Elevation, Partly in Section, of the Arrangement Employed by the Author for Testing Piston Friction and Using a Reciprocating Balance

Fig. 24—Transverse Elevation, Partly in Section, of the Author's Piston-Friction Testing-Device

are very reliable and consistent. To prevent internal cooling, a chamber of large capacity is fitted to the top of the cylinder so that the air displaced by the piston is not changed. Arrangements are made for operating this machine under the following different conditions:

(1) Atmospheric pressure
(2) A continuous air-pressure up to 45 lb. per sq. in., which is equal to the mean average pressure throughout the cycle
(3) A vacuum

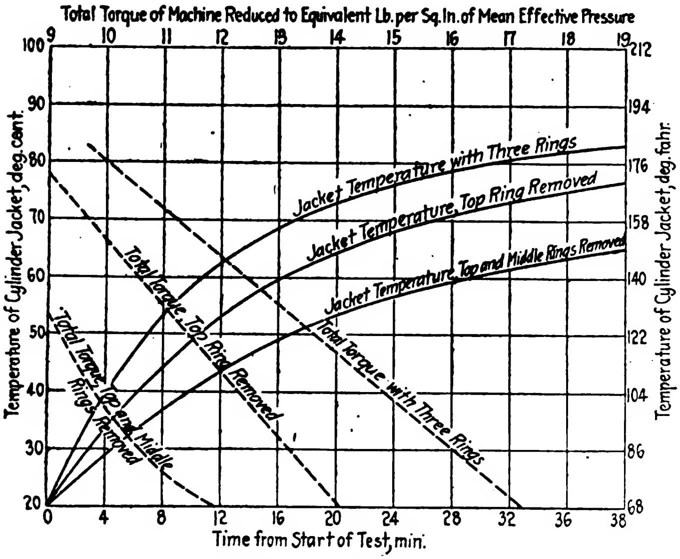


Fig. 25—Torque-Temperature Curves of an Aluminum Slipper Piston Obtained at a Speed of 1600 R.P.M. and No Air Pressure

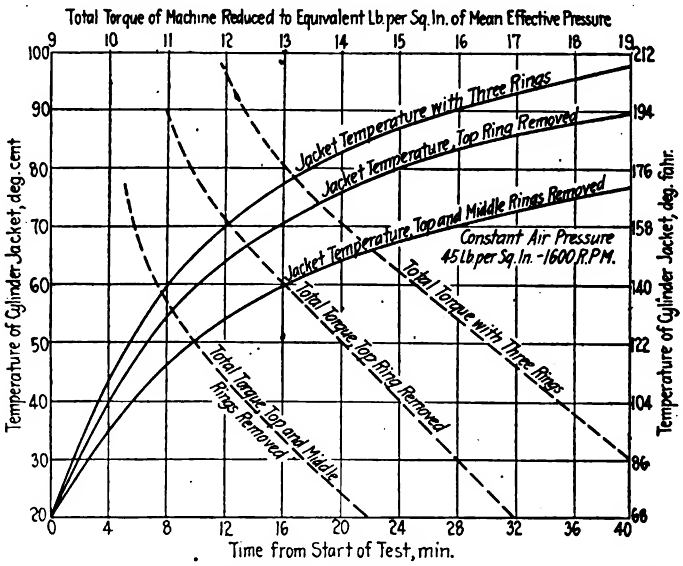


Fig. 26—Torque-Temperature Curves of an Aluminum Slipper Piston Obtained at 1600 R.P.M. and a Constant Air Pressure of 45 Lb. Per Sq. In.

(4) Compressing and expanding to a pressure of about 150 lb. per sq. in., by replacing the large-capacity with a plain cylinder-cover

The rate of gas leakage past the piston is determined by fitting a small and very light automatic air-inlet valve in the cylinder cover and measuring the amount of make-up air taken into the cylinder when compressing and expanding. Figs. 25, 26, 27 and 28 show some typical time-temperature diagrams taken with this machine and also the gross torque of the whole machine as measured by the

dynamometer. The latter should, of course, be read on the top horizontal scale of the diagram, against the temperature. The following deductions can be drawn from various tests on this machine.

(1) Piston friction is affected comparatively little by the fluid pressure on the piston
(2) Piston-rings account for a substantial proportion of the total piston friction
(3) Piston friction is at a minimum when compressing and expanding to such a pressure as to equal the inertia pressure; it is then abnormally low
(4) The amount of oil passed by any one type of piston is dependent only upon the speed and is proportional to it. At any given speed, it is practically unaffected by the pressure in the cylinder from a vacuum of 10 lb. per sq. in. to a positive pressure of 45 lb. per sq. in. This agrees with my experience with actual engines. I have always found the oil consumption to be a direct function of the speed and wholly independent of throttle opening, which latter determines, rather, whether or no the oil passed by the piston is completely burned

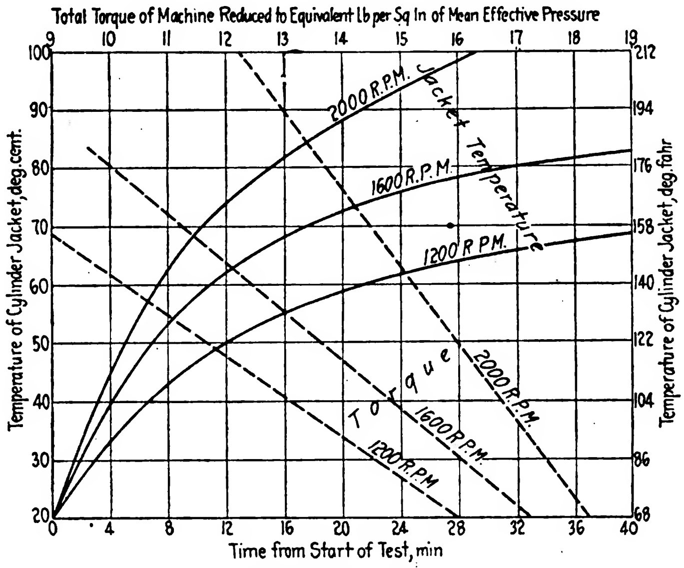


Fig. 27—Torque-Temperature Curves of an Aluminum Slipper Piston Obtained with No Air Pressure and All Three Rings in Place

APPENDIX 3.

Air Measurement

When investigating the performance of an internal-combustion engine it is essential, of course, to isolate and determine separately the influence of each of the main controlling factors. Above all, we must know both the mechanical and the combustion efficiencies, because it is upon these two factors that the power output and overall efficiency of an engine ultimately depend. We can arrive at the mechanical efficiency very easily and very closely by the motoring test, so long as we are careful to insure that this is carried out as nearly under running conditions as is possible.

The combustion efficiency, which is generally the most important factor of all, is very difficult to determine in the case of multi-cylinder engines. It is generally impossible to arrive at any just conclusion as to the combustion efficiency of a multi-cylinder engine by the usual method of measuring the power output and fuel consumption, on account of the large irregularities in distribution which are bound to occur. Thus, we may, and frequently do, find that one engine with a most efficient form of combustion-chamber and the like actually consumes more fuel per horsepower-hour than another of much less efficient design, simply because the distribution system of the latter is more uniform. At first sight, one might be led to suppose that, since the overall thermal efficiency of the second engine is higher, this therefore is inherently the more efficient engine of the two. However, by comparing the maximum mean effective pressure obtained from the two engines at their most favorable speeds, we shall have a more reliable comparison because, within reasonable limits, we are justified in assuming that however different the valve-timing, area and the like may be, the *maximum* volumetric efficiency of both engines will be about the same at some point in their speed range, and that each, at its most favorable speed, takes into the cylinder very nearly the same proportionate weight of working fluid per cycle. If this assumption were strictly correct, the maximum indicated mean pressure obtained by either engine would give an exact measure of the efficiency of combustion. Such an assumption cannot be confirmed without actual air measurement, although, as between generally similar engines designed to run at somewhat similar speeds, such an assumption probably is very nearly correct, provided always, of course, that the heat supplied to the carbureter and induction system bears the same relation to the weight of fuel in each case.

That the heat-input to the entering charge shall always be supplied in such a manner that it can be measured accurately and in absolute terms, that is, by electric-heater elements, is most desirable for all reliable research work and, unless means are available for measuring the air consumption accurately, it is a first essential. Whatever the variants may be, there is no doubt that, in the case of multi-cylinder engines, the true engine efficiency, as contrasted with the overall efficiency of engine and distribution system together, can be determined far more accurately from the maximum mean effective pressure developed than from any measurements of fuel consumption. Further, if the weight of air taken into the cylinders in a unit time can be measured, we have a means of ascertaining very closely the true thermal efficiency of an engine, no matter how irregular its distribution or how erratic its carbureter-setting may be, because, once we know definitely what use an engine makes of the air supplied to it, we know its true combustion efficiency; it is then incumbent upon the designer of the carbureter

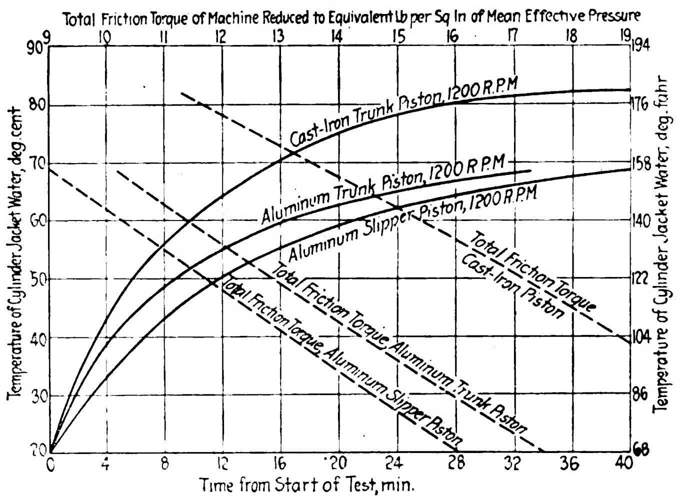


Fig. 28—Torque-Temperature Curves of a Cast-Iron Trunk, an Aluminum Trunk and an Aluminum Slipper Piston

and the induction system to see to it that the air is uniformly carbureted.

With a view to being able to measure accurately the air consumption of engines on the test bed, we determined, after a long series of somewhat disappointing results with air-boxes, calibrated orifices and electric-resistance methods, to design and construct a direct air-measuring device about the calibration of which there could be no uncertainty. This instrument, which consists of a calibrated gas-holder and some auxiliary apparatus, is shown diagrammatically in Figs. 4 and 5 of the paper. The holder consists of a sheet-steel bell guided by a central column and balanced in the usual manner. To prevent surging, the lower end of the bell is partially closed, leaving three holes open through which the water must pass. The size of these holes is such as not to interfere with the free flow of the water under normal conditions. For recording the amount of air consumed, a magnetically operated counter is employed, recording every 0.2 cu. ft. This counter is operated as follows:

A roller chain connected near the center of the crown of the bell passes over a sprocket pulley and is kept taut by the balance weight. A fine-pitch ratchet-wheel is mounted on the spindle of the chain-sprocket wheel and driven by a light friction clutch so that it rotates with it as the bell falls but remains stationary while it rises. This ratchet wheel operates a low-tension contact-maker, arranged so that contact is made and broken by each tooth of the ratchet. The contact-maker is connected up to an electromagnetically operated counter placed on the operator's desk, which records the number of contacts made or broken so long as the circuit is maintained. The pitch of the ratchet-wheel is designed so that contact is made and the counter advanced one digit for every 0.2 cu. ft. of air drawn from the holder.

A double-beat valve faced with rubber, also operated magnetically, is fitted to the air intake of the carbureter and arranged so that the supply of air to the engine can be drawn either from the atmosphere or from the holder, depending upon which face the valve is seating. The valve seats on the upper face under normal conditions, and air enters through the lower port from the atmosphere. The valve is snapped over from the upper to the lower seat by bringing the solenoid into operation, and air is then drawn from the holder. A small centrifugal fan driven by an electric motor is employed for charging the holder. This fan delivers air into the holder through an oil seal that forms an automatic non-return valve, and continues to do so until the bell reaches the top of its travel, when the latter automatically opens a switch and so stops the fan. The stopping of the fan permits the oil in the sealing box to flow back into the air inlet, and so prevents any air from being sucked through into the bell in either direction.

For carrying out fuel and air-consumption tests, the operation is as follows so soon as the observer is satisfied that the engine is developing its normal power output and that all temperature and other conditions have settled down to their normal value, he opens the cock and fills the fuel-measuring device from the main tank, as shown in Fig. 29; then he starts the fan to fill the holder. These operations occupy only a few seconds. As soon as the fuel-measuring device and the holder are filled with fuel and air, he closes the fuel cock, throws over the double-beat valve so that the engine then draws its fuel and air from their respective measuring devices, and then watches the rapid fall of fuel in the gage glass until it reaches the first mark. As the level of the fuel falls rapidly past this mark, he closes a switch and starts his stop-watch. The closing of the switch operates the revolution counter on the engine and the air-consumption counter simultaneously. The operator then waits until the level of the fuel falls past the second mark on the gage glass; at this instant, he closes the switch and stops his watch. He then has exact records available; they are (*a*) the number of revolutions during the consumption of a measured quantity of fuel; (*b*) the number of cubic feet of air consumed; and (*c*) the time taken during the consumption of fuel and air, this being required merely to give a true reading of the average engine speed, and as a check on the tachometer.

Repeated experiments made by different observers have indicated that the variation between different observers, due to the relatively small influence of the personal element, does not exceed about 0.50 per cent in practice; different readings by the same observer seldom vary more than 0.25 per cent and the absolute accuracy of measurement of an aggregate of several tests is probably in the neighborhood of 0.10 per cent. Errors due to changes of temperature of the air in the air-holder, because of sunshine, rain and the like, are reduced to the lowest possible minimum by the speed of operation. The holder is filled in about 30 sec. and its contents withdrawn in about 150 sec. on an average; thus, the length of time during which the bulk of the air remains in the holder is reduced to little more than 3 min. from start to finish. Readings are taken of the temperature of the air entering the air-bell, at the double-beat valve and close to the carbureter. Under ordinary atmospheric conditions, the

FIG. 29—PHOTOGRAPH OF THE FUEL-MEASURING DEVICE USED

temperature at these three points seldom varies by more than 1.5 deg. cent. (2.7 deg. fahr.).

Experiments with the air-measuring device coupled to our variable-compression engine have shown that, over a wide range of mixture-strength, the relationship between the indicated mean pressure and the weight of air entering the cylinder is practically constant; at all events, over the range from 5 to 35 per cent rich; and almost any distribution system, however bad, can be relied upon to keep within these limits. In practice, to determine the true combustion efficiency of any engine, it is necessary merely to adjust the carbureter to give a mixture for maximum power, that is, somewhere about 20 per cent rich, and to determine the efficiency from the ratio

$$E = P \div W C$$

where

C = a constant = 1.96 for rich gasoline mixtures
E = the efficiency
P = indicated horsepower
W = pounds of air per hour

TABLE 5—AIR CONSUMPTION

Fuel	Effective Lower Calorific Value, B.t.u. per lb.	Air-Fuel Ratio, at Correct Mixture-Strength	Heat Liberated by 1 Lb. of Air, B.t.u.	Value of Constant, C
Gasoline Samples				
A	19,200	15.05	1,275	1.940
B	19,020	14.70	1,295	1.975
C	19,120	14.80	1,293	1.970
D	18,900	14.60	1,295	1.970
E	19,090	14.90	1,282	1.950
F	19,250	15.00	1,285	1.955
G	18,920	14.70	1,288	1.960
Kerosene	19,100	15.00	1,275	1.940
Hexane	19,390	15.20	1,275	1.940
Heptane	19,420	15.10	1,285	1.955
Benzene	17,460	13.20	1,320	2.010
Toluene	17,660	13.40	1,315	2.000
Cyclohexane	18,940	14.70	1,290	1.965
Heptylene	19,320	14.70	1,320	2.010
Ether	16,830	13.00	1,295	1.975
Ethyl Alcohol,				
99 per cent	11,950	8.95	1,335	2.020
95 per cent	11,125	8.40	1,330	2.015

Table 5 gives the total effective internal energy liberated by 1 lb. of air when fully saturated with various fuels. These values must not be confused with the figures given previously for the internal energy of different fuel-air mixtures, or with the volumetric efficiency figures, both of which include the fuel vapor as well as the air. Although somewhat empirical, the figures given in the third and fourth columns are fairly accurate. From the figures in Table 5 it will be seen that, whatever fuel is used, the energy liberated by 1 lb. of air will always be approximately 1300 B.t.u. The extreme variation over the entire range of representative fuels is from 1275 to 1335 B.t.u., while the variation over the whole range of gasolines is only from 1275 to 1295 B.t.u., depending upon the proportion of *aromatic* present in the fuel.

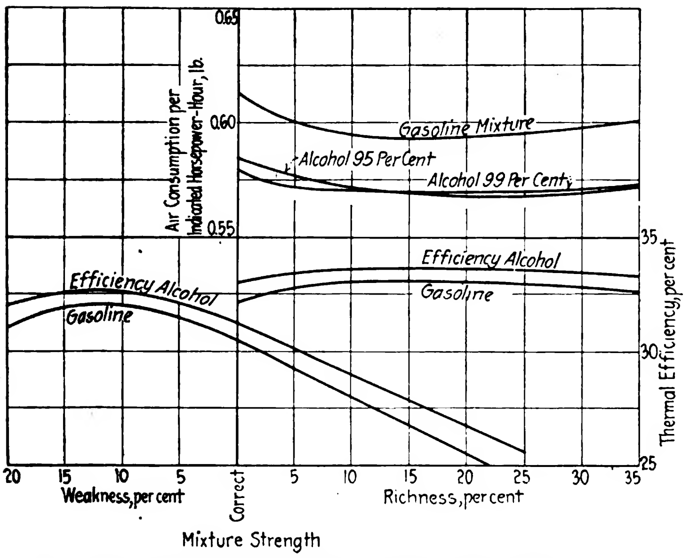


FIG. 30—CURVES SHOWING THE THERMAL EFFICIENCY AND AIR CONSUMPTION FOR VARIOUS MIXTURE-STRENGTHS

TABLE 6—TEST RESULTS ON GASOLINE SAMPLE D WITH A COMPRESSION-RATIO OF 5 TO 1

Mixture Strength, per cent	Air Consumption Per Hour, lb.	Indicated Mean Effective Pressure, lb. per sq. in.	Indicated Horsepower	Air Consumption Per Indicated Horsepower-Hour, lb.	Indicated Thermal Efficiency, per cent
Correct	196.0	132.0	32.0	6.13	32.10
+ 5	196.5	135.0	32.7	6.00	32.80
+ 10	197.0	136.5	33.1	5.95	33.10
+ 15	197.5	137.5	33.3	5.93	33.20
+ 20	198.1	138.0	33.4	5.94	33.15
+ 25	198.8	138.0	33.4	5.96	33.05
+ 30	199.5	137.5	33.3	5.98	32.85
+ 35	200.0	136.5	33.1	6.04	32.70

The following test figures in Tables 6 to 9 and the curves of Fig. 30 are taken from actual tests conducted in the manner already described. Table 6 shows the total air-consumption, the indicated mean pressure, the pounds of air per indicated horsepower and the indicated thermal efficiency, calculated from air consumption, on gasoline, with a compression-ratio of 5 to 1, with a constant heat-input of 0.0433 B.t.u. per revolution and at a constant speed of 1500 r.p.m. Table 6 gives the results obtained experimentally over a range of mixture-strength from that giving complete combustion with no excess of air up to a mixture-strength that has a 35-per cent excess of gasoline.

Table 7 shows the same determination for 99-per cent ethyl alcohol and Table 8 the same for 95-per cent ethyl alcohol. It will be observed from Tables 7 and 8 that the air consumption in pounds per indicated horsepower-hour is a little lower in the case of the alcohols than in the case of gasoline. This is due partly to the fact that, as shown previously, the total heat energy liberated by the consumption of 1 lb. of air is very slightly greater in the case of alcohol and in part also to the fact that, owing to the lower mean cycle temperature, the efficiency obtained on alcohol is always some 2 to 3 per cent higher than on gasoline or benzene, as shown in Fig. 3.

It will be observed that in all cases the air consumption in pounds per indicated horsepower-hour is the same to within very close limits over the whole range of mixture-strengths from 5 to 35 per cent rich. That is, no matter what the mixture-strength may be, so long as there is an excess of fuel present, the thermal efficiency, based on the air consumption or, more strictly speaking, on that portion of the fuel that is burnt, is virtually the same. Incidentally, it is interesting to note that, as the

TABLE 7—TEST RESULTS ON 99-PER CENT ETHYL ALCOHOL WITH A COMPRESSION-RATIO OF 5 TO 1

Mixture Strength, per cent	Air Consumption Per Hour, lb.	Indicated Mean Effective Pressure, lb. per sq. in.	Indicated Horsepower	Air Consumption Per Indicated Horsepower-Hour, lb.	Indicated Thermal Efficiency, per cent
Correct	199.0	141.0	34.20	5.82	32.90
+ 5	199.5	143.0	34.60	5.77	33.30
+ 10	200.0	144.5	35.00	5.72	33.65
+ 15	201.0	145.5	35.25	5.70	33.70
+ 20	202.0	146.5	35.50	5.69	33.75
+ 25	203.0	147.0	35.60	5.70	33.70
+ 30	204.0	147.3	35.70	5.72	33.65
+ 35	205.0	147.6	35.80	5.73	33.60

TABLE 8—TEST RESULTS ON 95-PER CENT ETHYL ALCOHOL WITH A COMPRESSION-RATIO OF 5 TO 1

Mixture Strength, per cent	Air Consumption Per Hour, lb.	Indicated Mean Effective Pressure, lb. per sq. in.	Indicated Horsepower	Air Consumption Per Indicated Horsepower-Hour, lb.	Indicated Thermal Efficiency, per cent
Correct	203.0	145.0	35.10	5.79	33.10
+ 5	203.5	146.7	35.50	5.72	33.60
+ 10	204.0	148.0	35.80	5.71	33.65
+ 15	205.0	149.0	36.00	5.70	33.70
+ 20	206.0	149.5	36.15	5.70	33.70
+ 25	207.0	150.0	36.25	5.70	33.70
+ 30	208.0	150.3	36.30	5.71	33.65
+ 35	209.0	150.5	36.35	5.74	33.40

mixture-strength is enriched beyond the point of complete combustion, the thermal efficiency, based on that portion of the fuel which is utilized, rises at first and then remains nearly constant over a wide range; but, in every case, it actually reaches a maximum at about 20 per cent rich. The curves in Fig. 30 show the thermal efficiency as ascertained in this manner over a range of mixture-strengths from correct to 35 per cent rich. The efficiency on the weak side, as determined from the fuel consumption alone, is shown in dotted lines. That the efficiency as reckoned by the air consumption should be so uniform over a wide range of mixture-strengths on the rich side, as it has been found to be, is perhaps somewhat of a coincidence in view of the wide variation in the nature of the chemical reactions, the change of specific volume and the like.

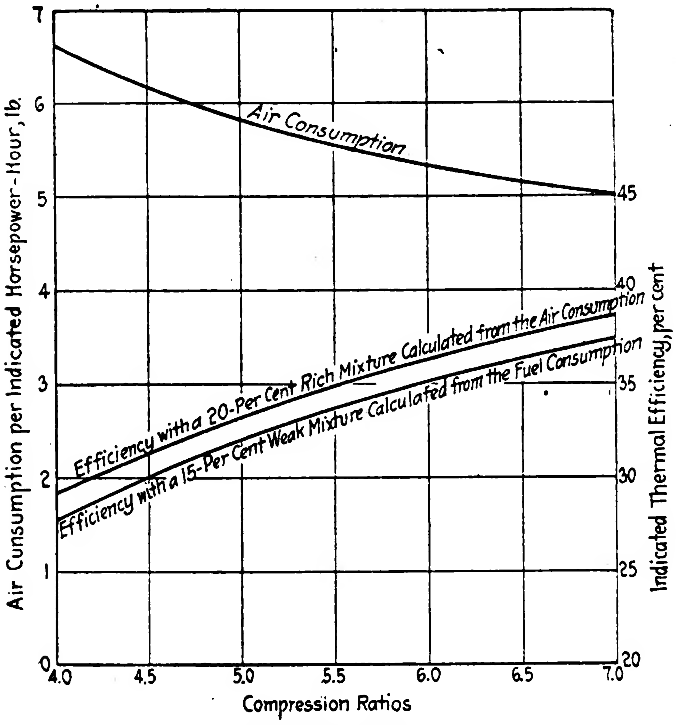


FIG. 31—THERMAL EFFICIENCY AND AIR CONSUMPTION CURVES FOR VARIOUS COMPRESSION RATIOS

Table 9 and Fig. 31 show the efficiency as determined from the air consumption when running on benzol with a mixture-strength varying anywhere from 10 to 30 per cent rich, and at compression-ratios ranging from 4 to 1 to 7 to 1, while the lowest line shows the maximum thermal efficiency as ascertained from the fuel consumption with the mixture adjusted in each case to give the highest economy; namely, about 15 per cent weak. The efficiency as calculated from the air consumption will always be slightly higher than that determined by the fuel consumption, the slight difference being due in part to the small proportion of fuel that is lost in carburetion or otherwise escapes combustion by adhering to the cold cylinder-walls. As a result of these investigations, I am convinced that, for tests on multi-cylinder engines in which it is impossible to insure that each cylinder receives a mixture of exactly the same strength, the air-measurement test gives a very much closer approximation to the true thermal efficiency of such an engine than can possibly be arrived at from the fuel consumption; and that, where means are not available for measuring the air consumption accurately, the maximum indicated mean effective pressure, suitably corrected for the compression-ratio, gives a fairly true comparison at all events in the case of engines of generally similar type and size.

It may be argued that to reckon the thermal efficiency of an engine by its air consumption is of academic interest only, and that it is the efficiency on fuel consumption alone that is of any practical or commercial value. Such an argument is, however, fallacious; if it can be shown that an engine consumes its air efficiently, then it is essentially an efficient engine, and to render it efficient also on fuel is purely a matter of carburetion and distribution.

TABLE 9—TEST RESULTS WITH FUEL BENZOL, ABOUT 20-PER CENT RICH; VARYING COMPRESSION-RATIO

Compression-Ratio	Air Consumption Per Hour, lb.	Indicated Mean Effective Pressure, lb. per sq. in.	Indicated Horsepower	Air Consumption Per Indicated Horsepower-Hour, lb.	Indicated Thermal Efficiency, as Found by Air Measurement, per cent	Indicated Thermal Efficiency, as Found by Fuel Measurement, 15-Per Cent Weak, per cent
4 to 1	200.5	125.0	30.3	6.62	29.2	27.7
5 to 1	194.0	136.5	33.1	5.82	33.2	32.0
6 to 1	188.0	145.0	35.2	5.34	36.2	35.0
7 to 1	184.0	152.0	36.8	5.00	38.5	37.3

APPENDIX 4

INTERNAL ENERGY OF THE WORKING FLUID

Some years ago the Gaseous Explosions Committee of the British Association prepared a curve showing the total internal energy of the working fluid comprising the products of combustion of an air-gas mixture over a wide range of temperature. This curve was constructed after a very careful analysis of all the reliable investigations available at the time. It would appear, however, in the light of more recent knowledge, that the change in apparent specific heat at the higher temperatures has been somewhat over-rated; also it is applicable only to a mixture of coal gas and air, the characteristics of which differ considerably from those of an air-gasoline mixture.

From the results of Tizard and Pye's investigations, it becomes possible to construct a similar curve for a gasoline-air or benzene-air mixture. Such a curve is shown in Fig. 32 and is probably about as accurate as the present state of knowledge will permit. From such a curve, and by making certain assumptions, it is possible to deduce the temperature of the working fluid at almost any point in the cycle. Fig. 32 shows a graphic construction by which, once the heat of combustion of the fuel and the thermal efficiency are known, the range of temperature throughout the expansion-stroke can be determined with a fair degree of accuracy. In the construction of such a graph and to keep it reasonably applicable to a wide range of conditions, it is necessary to compromise to some extent and to take mean values.

Thus, the energy curve shown applies strictly only to

a benzene-air complete-combustion mixture at a compression-ratio of 5 to 1. However, the effect of a change in the compression-ratio is negligible within the limits used on the constant-volume cycle; as is the effect, also, of replacing benzene by any other hydrocarbon fuel. If used for a fuel such as alcohol or ether, however, the error becomes appreciable, owing to the different specific heat of the products of combustion. For the same reason, the curve does not apply to mixtures which are either weaker or richer than the chemically correct mixture, although here again the divergence is very small within the range available with a homogeneous mixture.

In Fig. 32, the internal energy curve is plotted in terms of British thermal units per standard cubic inch on a vertical scale, against the temperature on a horizontal scale. The other full-line curve shows the energy present as heat, so that the difference between the two curves shows the chemical energy stored in the products of dissociation. Zero energy is taken at 100 deg. cent. (212 deg. fahr.) as being an average temperature at the beginning of compression. Variations in this temperature will have but little influence. The explanation given below of the use of the diagram is supplemented by an example worked out for the following data, the construction lines of the example being shown dotted in Fig. 32.

Compression-ratio, R,	= 5 to 1
Energy content	= 46.2 B.t.u. per cu. in.
Heat loss during combustion	= 6 per cent
Heat loss during expansion	= 6 per cent

There are three factors in an actual engine which modify the temperature attained by the combustion of a mixture of any given energy content. They are the

(1) Heat put into the mixture by compression
(2) Loss due to cooling by the walls of the combustion-chamber during combustion
(3) Effective weakening of the mixture due to dilution with the residual exhaust products

Factor (1) is allowed for by laying off the heats of compression for various ratios by the marks "$R = 5$," etc., on the line $P\ P_1$ near the bottom of the diagram. The energy content is then marked off above this on the vertical line $O_1\ Y_1$ representing the 100 deg. cent. (212 deg. fahr.) starting-point. In the example, the 46.2 B.t.u. energy content is laid off above the 3.6 B.t.u. of compression, making a total of 49.8 B.t.u., this being the gross energy content from which the losses due to factors (2) and (3) must be deducted. This is done in the following manner:

On the horizontal scale C is marked the effective energy loss due to dilution with residual exhaust, assumed to be at 1000 deg. cent. (1832 deg. fahr.). Scale E shows the percentage loss due to cooling during combustion. This is laid off at any figure which previous experience shows as probable for the type of combustion-chamber in question; this is 6 per cent in the example. A line is then drawn between these two points, and the point of intersection of this line with the scale D gives the total percentage loss due to these two causes; this is 11.5 per cent in the example.

To transfer this to the diagram, a line is dropped vertically from the above intersection point. Another line is drawn from the point on the line $O_1\ Y_1$ giving the gross British thermal units per cubic inch to the suitable compression point on the line $P\ P_1$, and representing 100 per cent on scale D; this is 49.8 B.t.u. per cu. in. in the example. From the intersection of the above two lines, a horizontal line is run to the energy scale on one side,

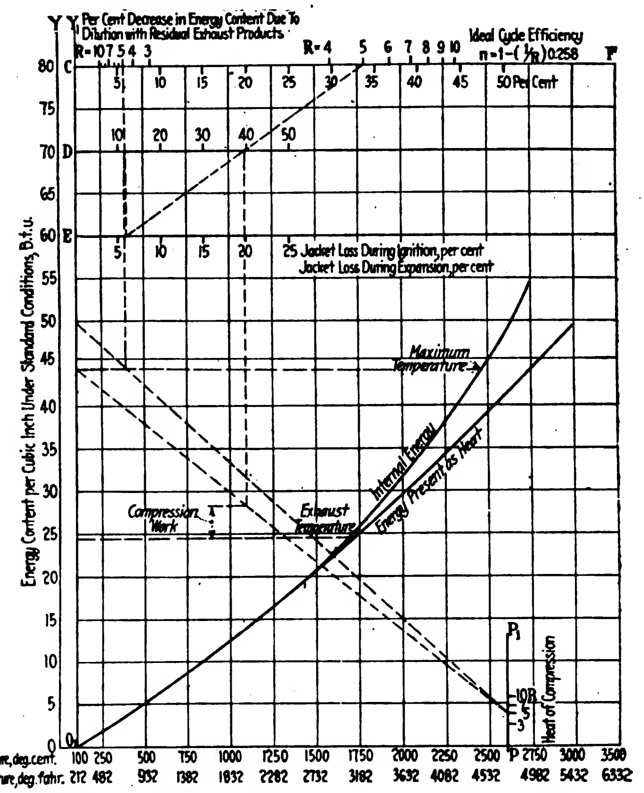


FIG. 32—INTERNAL ENERGY DIAGRAM FOR THE WORKING FLUID OF AN INTERNAL-COMBUSTION ENGINE RUNNING ON VOLATILE HYDROCARBON FUELS

and the energy curve on the other. The point on the energy scale shows the net energy available for expansion; it is 44.5 B.t.u. per cu. in. in the example. From the energy-temperature curve, the actual flame temperature can be read off; this is 2475 deg. cent. (4487 deg. fahr.) in the example.

The drop in temperature during the expansion-stroke depends on the two factors of (a), external work done and (b) heat loss to the walls. The net power output is given as a percentage of the heat content of the mixture on scale F, the formula used being $n = 1 - (1/R)^{0.258}$. This covers all dissociation and similar effects, but not wall losses. The wall loss during expansion is laid off on scale E. A line drawn between these points gives their sum on scale D as before. A perpendicular from this point is dropped to meet a line from the net-energy point on $O_1\ Y_1$ to the suitable-compression point on the line PP_1. As the gross work done during expansion is the sum of the net work mentioned above and the compression work, this latter amount, which is 3.6 B.t.u. in the example, must be laid off below the above intersection point, to find the energy content at the end of expansion, which is 24.5 B.t.u. in the example. The corresponding final temperature, 1675 deg. cent. (3047 deg. fahr.) in the example, can then be read off from the energy curve.

Taking an actual example from the variable-compression-engine data, with a correct mixture of an energy content of 46.2 B.t.u. per cu. in. and a compression-ratio of 5 to 1, the actual maximum flame-temperature, as obtained from the above diagram in Fig. 32, allowing for the additional heat of compression, the wall loss during combustion and the dilution by residual exhaust products, will be 2475 deg. cent. (4487 deg. fahr.), corresponding to an energy content of 44.5 B.t.u. per standard cu. in. At a ratio of 5 to 1, the observed indicated thermal efficiency is 31 per cent; of this, 5 per cent is due to the

change in specific volume of the mixture, so that the heat drop is 46.2 x 31 x 100/105 = 13.6 B.t.u. per cu. in. Add to this the 3.6 B.t.u. of compression work restored during expansion, and the 6 per cent of 46.2 or 2.8 B.t.u. of wall loss during expansion, and the total heat-drop during expansion becomes 20.0 B.t.u. per cu. in., leaving a final energy content of 24.5 B.t.u. per cu. in. which, it will be observed, coincides with the figure found in the example under the same conditions. The corresponding final temperature is 1675 deg. cent. (3047 deg. fahr.).

While affecting the final temperature directly, it should be observed that the loss of heat during expansion has only a slight influence on the actual efficiency; this has been ignored in the construction, because much of it is lost late in the expansion-stroke where its value is less. Another slight error allowed to remain in the construction, for the sake of simplicity, is that a percentage of the *net* heat available during combustion is deducted for the jacket loss during expansion; whereas this is given as a proportion of the *total* heat available in the fuel. The error due to this cause is however very small, being in the case considered 2.8 [(46.2 — 44.5) ÷ 44.5] = 0.11 B.t.u. per cu. in., and can be ignored safely.

APPENDIX 5

Influence of Compression-Ratio Upon Power Output and Efficiency

The influence, both theoretical and observed, of the compression-ratio upon thermal efficiency has been dealt with in the main portion of the paper and Table 3 gives both Tizard and Pye's deductions and the observed figures over a range from 4.0 to 1 up to 7.5 to 1. The outstanding feature of all of the experiments has been the exceedingly close agreement between the theoretical and the observed thermal efficiencies throughout practically the whole range with the exception, perhaps, of the lower compressions where the observed efficiency is somewhat lower than would be expected. As regards power output, however, there is very marked divergence between the observed and the theoretical results, because the indicated mean effective pressure does not rise with increase of compression at anything approaching the rate at which one might expect. It is obvious that, if all mechanical and temperature conditions remain constant, the increase in both efficiency and power output with an increase of compression must also be the same, unless the

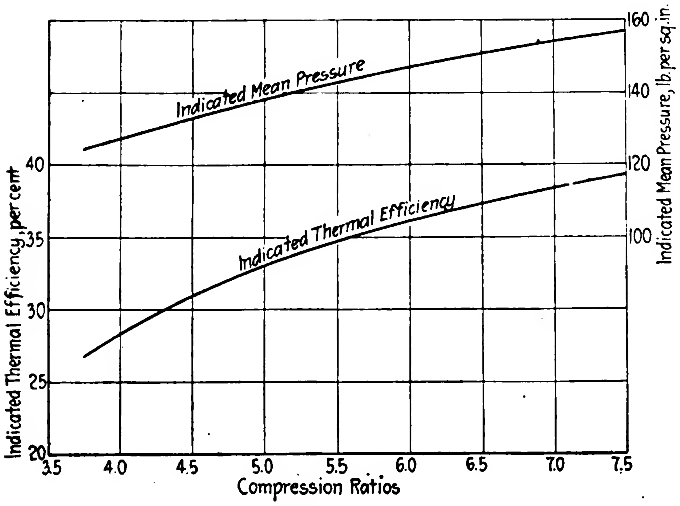


Fig. 33—Indicated Mean Effective Pressure and Thermal Efficiency Curves for 95-Per Cent Ethyl Alcohol at Varying Compression-Ratios

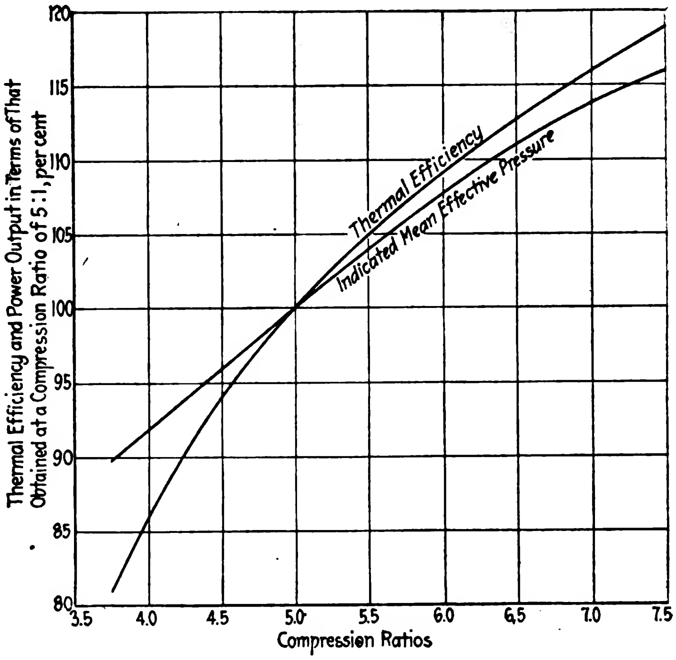


Fig. 34—Correction Curves for Indicated Mean Effective Pressure and Thermal Efficiency

volumetric efficiency undergoes some change. That the mechanical conditions remain unaltered is certain, for the change in compression is effected by raising or lowering the whole cylinder together with its overhead camshaft, carbureter, induction pipe and ignition gear; while, as to the temperature conditions, the only respect in which they can alter appreciably is that the exhaust-valves are somewhat cooler at the higher compression-ratios. In fact, as shown in Appendix 8, the total heat-flow to the cylinder walls is, if anything, slightly lower at the higher compression-ratios. Therefore, such changes of temperature as can occur will tend to increase the weight of charge retained in the cylinder, if, indeed, they are of sufficient magnitude to have any appreciable influence. Despite this, however, the volumetric efficiency has been found to fall rapidly with increase of compression. The reason for this is still very obscure. If it occurred at one speed only it might be attributed to resonance or other effects in the pipe work or, as W. S. James suggested to me, to the greater depression in the cylinder at the moment when the inlet-valve first opens. Observations at widely varying speeds have shown, however, that the change in volumetric efficiency is, in fact, substantially the same at all speeds; and recent experiments, carried out at the Royal Aircraft Establishment on another engine in which the compression could be varied by inserting packing-pieces under the cylinder, have given similar results. Further, the general experience with aircraft engines has shown that, while the use of a high compression-ratio greatly increases the efficiency, the gain in power output is much less marked.

Fig. 33 shows the variation both in thermal efficiency and in mean effective pressure as observed over a range of compression from 3.75 to 1 up to 7.5 to 1. The fuel used in this instance was 99-per cent ethyl alcohol, this being chosen as one of the few which could be used safely at the highest compression-ratio. As explained previously, the efficiency and power output on this fuel are both somewhat higher than on gasoline or benzol. Within their safe limits, however, all of the other fuels tested have shown precisely the same characteristic variation. Fig. 34 shows the correction curves in terms of percent-

age, which can be deduced from the observed results as shown in Fig. 33.

Further tests, with the air-measuring device in use, have shown that as the compression-ratio is raised the weight of air per cycle is reduced to an extent that accounts almost exactly for the discrepancy. The precise cause of this change in volumetric efficiency still remains somewhat of a mystery. It is possible to produce several plausible arguments to account for an increase in volumetric efficiency with increase of compression, but to account for a decrease is much more difficult.

APPENDIX 6

INFLUENCE OF CYLINDER SIZE ON PERFORMANCE

The comparative figures given in Table 10 may be of some interest. They are taken from three single-cylinder experimental engines, all of them being similar in that

(1) They had valves fitted directly in the cylinder-heads

(2) They had precisely the same valve-opening diagram

(3) The speed chosen for comparative purposes in all cases is that at which the mean gas-velocity through the inlet-valves is 130 ft. per sec., and through the exhaust 150 ft. per sec.

(4) All three engines were fitted with aluminum slipper-type pistons of similar design

(5) The compression-ratio in all cases was 4.8 to 1, and the fuel used was American aviation gasoline

TABLE 10—COMPARISON BETWEEN SINGLE-CYLINDER EXPERIMENTAL ENGINES

	Engine A	Engine B	Engine C
Bore, in.	3.25	4.50	8.00
Stroke, in.	4.00	8.00	11.00
Brake Horsepower	8.48	35.4	118.0
Speed, r.p.m.	1,750	1,750	1,250
Piston Speed, ft. per min.	1,166	2,333	2,290
Mechanical Efficiency, per cent	83	86	88
Brake Mean Effective Pressure, lb. per sq. in.	114	126	135
Indicated Mean Effective Pressure, lb. per sq. in.	137.5	146.5	153.0
Fuel Consumption, lb. per b.hp-hr.	0.543	0.506	0.474
Fuel Consumption, lb. per i.hp-hr.	0.451	0.435	0.416
Brake Thermal Efficiency, per cent	24.6	26.4	28.2
Indicated Thermal Efficiency, per cent	29.6	30.8	32.0
Relative Efficiency, per cent	63.5	66.1	68.7

From these results it is possible to arrive at an approximate correction-figure for cylinder capacity somewhat as shown in Fig. 35. This must not be taken too seriously, for to generalize from the results of only three engines not entirely similar would be very unsafe, even though much other corroborative evidence has been found in support of the relationship shown in this figure.

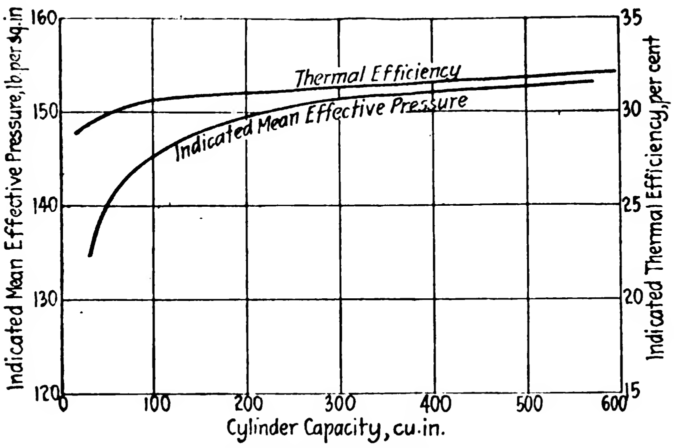


FIG. 35—CORRECTION CURVES FOR CYLINDER CAPACITY

APPENDIX 7

INFLUENCE OF CYLINDER TEMPERATURE ON POWER OUTPUT

Under full-load conditions, the indicated horsepower rises as the temperature of the cylinder is reduced, due to the increase in the volumetric efficiency. In the case of our variable-compression engine, which is a fairly normal example, direct measurements of volumetric efficiency have shown that the weight of charge falls 0.5 per cent for every 10-deg. cent. (18-deg. fahr.) rise of mean water temperature. It may be deduced from this that the rise in temperature of the air entering the cylinder in this particular engine amounts to approximately one-sixth of the temperature-difference between the air and the circulating water over the range from 30 to 90 deg. cent. (86 to 194 deg. fahr.). Whether the brake horsepower increases or decreases with the cylinder-jacket temperature depends almost solely upon the piston design. With the ordinary trunk piston having large areas of surface in contact with the cylinder walls, the influence of the viscosity of the oil upon piston friction is such that, despite the decrease in the indicated horsepower with hot jacket-water, the brake horsepower rises or, in other words, with a cold cylinder barrel, the increased friction more than counterbalances the increase in indicated power.

With a very light slipper piston, such as is fitted to our variable-compression engine, the brake horsepower rises very slightly as the temperature of the jacket water is reduced. With crosshead pistons, such as were used in the tank engines, the brake horsepower almost invariably rose by about 2 per cent when the mean jacket temperature was reduced from 80 to 30 deg. cent. (176 to 86 deg. fahr.), or very nearly in proportion to the increase in indicated power over the same temperature range.

APPENDIX 8

DISTRIBUTION OF HEAT IN A HIGH-SPEED ENGINE

The following test results show the observed distribution of heat in our variable-compression engine under various conditions of operation. Since they were taken in circumstances that make for a very high degree of accuracy, and under a fairly wide range of conditions, they are perhaps of some interest. With the exception of the tests on hydrogen, when the power was controlled by reducing the fuel supply and therefore the flame temperature, there is nothing novel. In all cases, except with hydrogen, the tests were made at a mixture strength ranging from 5 to 10 per cent weak. The tests were carried out in three groups. Group A comprised tests at a constant compression-ratio and constant fuel-air ratio, but with varying speed, on two fuels; also, one series of tests at a higher compression ratio. Group B included tests at constant compression-ratio, constant fuel-air ratio and constant speed, but with the mean effective pressure varied by throttling, on two fuels. Group C was composed of tests at constant compression-ratio and constant speed, but with the mean effective pressure varied by varying the fuel-air ratio as in a Diesel engine; hydrogen gas being used as fuel in this instance. In all cases the following precautions were observed:

(1) The circulating water was maintained at a constant temperature of 60 deg. cent., plus or minus

2 deg. cent. (140 deg. fahr., plus or minus 3.6 deg. fahr.)

(2) The heat-input to the carbureter was adjusted to bear a constant proportion to the weight of fuel consumed, except in the case of hydrogen when the carbureter was unheated

(3) In Groups A and B, the fuel-air ratio in all cases was such as to give approximately 10 per cent excess of air over that required for complete combustion of the fuel, the air consumption being measured and adjusted in each case

(4) No readings were recorded until all temperature conditions had been stabilized for a considerable period after each change of state

The amount of heat dissipated, to the exhaust, by radiation and the like, is arrived at by difference in each case.

In all cases the indicated thermal efficiency can be taken as accurate to within about 0.5 per cent, and the heat to cooling water to within 1 per cent. Also, in all cases the heat produced by piston friction and that lost by radiation balanced at approximately 1500 r.p.m. The water temperature at which the readings were taken was that which the cylinder attains when motored continuously at 1500 r.p.m.; that is, 45 or 60 deg. cent. (113 or 140 deg. fahr.) above atmospheric temperature.

TABLE 11—TESTS SHOWING HEAT DISTRIBUTION IN A HIGH-SPEED INTERNAL-COMBUSTION ENGINE

Group A—Compression-Ratio, 3.8 to 1; Fuel, 95-Per Cent Ethyl Alcohol				
Engine Speed, r.p.m.	975	1,300	1,500	1,700
Piston Speed, ft. per min.	1,300	1,733	2,000	2,266
Heat to Indicated Horsepower, per cent	26.9	27.0	26.9	27.0
Heat to Cooling Water, per cent	25.1	24.7	24.4	24.2
Heat to Exhaust, Radiation, etc., per cent	48.0	48.3	48.7	48.8
Total Heat, per cent	100.0	100.0	100.0	100.0
Group A—Compression-Ratio, 3.8 to 1; Fuel, Grade A Gasoline				
Engine Speed, r.p.m.	975	....	1,500	1,200
Piston Speed, ft. per min.	1,300	....	2,000	2,266
Heat to Indicated Horsepower, per cent	25.9	....	26.1	26.1
Heat to Cooling Water, per cent	30.4	....	28.0	27.0
Heat to Exhaust, Radiation, etc., per cent	43.7	....	45.9	46.9
Total Heat, per cent	100.0		100.0	100.0
Group A—Compression-Ratio, 7 to 1; Fuel, 95-Per Cent Ethyl Alcohol				
Engine Speed, r.p.m.	975	1,300	1,500	....
Piston Speed, ft. per min.	1,300	1,733	2,000	....
Heat to Indicated Horsepower, per cent	37.6	38.1	38.3	....
Heat to Cooling Water, per cent	25.4	24.3	23.9	....
Heat to Exhaust, Radiation, etc., per cent	37.0	37.6	37.8	....
Total Heat, per cent	100.0	100.0	100.0	
Group B—Throttling at Constant Fuel-Air Ratio. Compression-Ratio, 5.45 to 1; Engine Speed, 1500 r.p.m.; Piston Speed, 2000 ft. per min.; Fuel, 95-Per Cent Ethyl Alcohol				
Percentage of Maximum Indicated Horsepower	100.0	80.0	60.0	40.0
Heat to Indicated Horsepower, per cent	34.8	35.0	35.0	34.8
Heat to Cooling Water, per cent	24.1	26.0	29.2	33.0
Heat to Exhaust, Radiation, etc., per cent	41.1	39.0	35.8	32.2
Total Heat, per cent	100.0	100.0	100.0	100.0
Group B—Compression-Ratio, 5.45 to 1; Engine Speed, 1500 r.p.m.; Piston Speed, 2000 ft. per min.; Fuel, Grade A Gasoline				
Percentage of Maximum Indicated Horsepower	100.0	80.0	60.0	40.0
Heat to Indicated Horsepower, per cent	33.5	34.0	34.1	33.5
Heat to Cooling Water, per cent	26.5	28.2	31.8	35.5
Heat to Exhaust, Radiation, etc., per cent	40.0	37.8	34.1	31.0
Total Heat, per cent	100.0	100.0	100.0	100.0
Group C—Mean Effective Pressure Varied by Varying Fuel-Air Ratio from 15 Per Cent Excess of Air Upward; Compression-Ratio, 5.45 to 1; Engine Speed, 1500 r.p.m.; Piston Speed, 2000 ft. per min.; Fuel, Hydrogen				
Percentage of Maximum Indicated Horsepower	100.0	80.0	60.0	40.0
Heat to Indicated Horsepower, per cent	33.3	35.6	38.2	40.0
Heat to Cooling Water, per cent	23.6	24.9	25.3	28.6
Heat to Exhaust, Radiation, etc., per cent	43.1	39.5	36.5	31.4
Total Heat, per cent	100.0	100.0	100.0	100.0

APPENDIX 9

EFFICIENCY UNDER REDUCED LOADS

Tests made recently on our single-cylinder research-engine have shown that, as the load is reduced by throttling and with the ignition set to give the best results on full load, the fuel consumption per indicated horsepower-hour increases slightly as the load is reduced, but that if, at each throttle-opening, the ignition timing is advanced as the load is reduced, the fuel consumption per indicated horsepower-hour remains substantially constant throughout the range from 30 to 100 per cent of full-load torque.

The same procedure was adopted in all these tests, and a very large number have been made on different fuels; that is, at each throttle-opening the whole range of mixture strength was explored. The circulating water was maintained throughout at the same temperature. The heat-input to the carbureter was maintained proportional to the load; that is, at full load the heat-input was at the rate of 65 B.t.u. per min., at one-half load 32.5 B.t.u. per min., and so on. Also, at each throttle position the mechanical losses were measured at intervals by motoring. This was done by switching off the ignition and changing over the armature circuit of the dynamometer simultaneously, the combined operation taking less than 1 sec., and being effected without any appreciable change in speed.

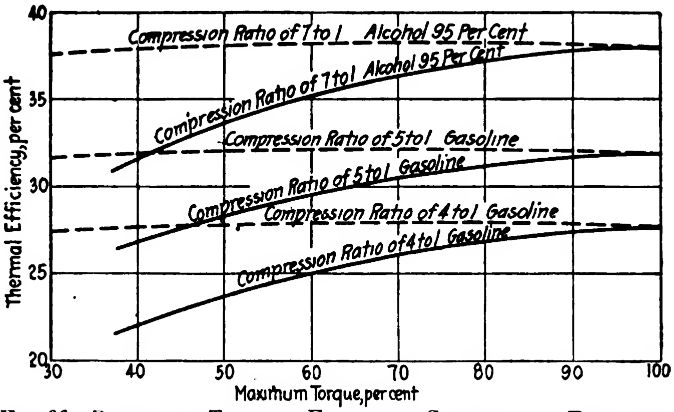


FIG. 36—POWER AND THERMAL EFFICIENCY CURVES FOR A THROTTLED ENGINE USING GASOLINE AND 95 PER CENT ETHYL ALCOHOL AT VARIOUS COMPRESSION-RATIOS

In Fig. 36, full-line curves show the results obtained with fixed ignition and the dotted curves give results with the ignition adjusted for each change in load, in both cases, at three different compression-ratios, on gasoline and alcohol. The former condition, with fixed ignition, is probably the only practical one, but the substantial gain in efficiency effected by advancing the spark when operating on light loads is very noticeable. There is, of course, nothing novel in such experiments except that they were carried out under conditions that insured an unusual degree of accuracy.

THE DISCUSSION

CHAIRMAN H. M. CRANE:—I hope that the members have some realization of the debt we owe Mr. Ricardo for

this paper. Many of us have prepared papers of our own and, even when we have the facts available, the mere assemblage of them into a synopsis of this kind requires a great effort and much time, especially when it is done with the care that has been used in this instance. The problem of distribution is brought out in this paper. Each result of Mr. Ricardo's test indicates the desirability of maintaining a fairly close ratio of gas to air to obtain the best results. It is very evident that this cannot be done in a multi-cylinder engine without securing the most perfect possible distribution of the fuel mixture.

C. P. GRIMES:—I appreciate especially Mr. Ricardo's discussion of fuel conditions on the cylinder wall and turbulence. I made a long series of tests upon some cylinders in which I could control and measure these temperatures very accurately. My ideal was to obtain more power and economy from a given bore and stroke. The economy increased very rapidly with the temperature, up to a 550-deg. fahr. temperature of the combustion-chamber wall. This, I think, bears out very clearly Mr. Ricardo's explanation of the reason for desiring turbulence, to take the fuel from the cool cylinder walls and mix it with the other portions of the charge. I feel certain that the fuel economy I obtained came from heating these walls hot enough to vaporize the fuel from them with what little turbulence existed.

In 1912 a car ran to California and back and employed kerosene as fuel. The products of combustion were used in the carbureter instead of utilizing moisture as had been done previously. I have found tractor builders in favor of such usage but they experience the same result expressed by Mr. Ricardo, in that only about 80 per cent of the power is realized. Maximum economy usually is assured by 15 per cent of excess air. I suppose this is for the purpose of supplying excess oxygen to those few fuel particles that do not utilize it readily. The introduction of exhaust gases reduces the volume of the active charge. I should think this would cancel the benefit derived from the 15 per cent of excess air on account of the increased dilution. I have been able to get economy and power by decreasing the compression and increasing the cylinder-head temperature. These results are at variance with some of Mr. Ricardo's remarks; however, they cover months of experiment and seem to be trustworthy.

I agree with Mr. Ricardo on the sensitiveness of pressure. We ran an engine for 1 hr. at 2250 r.p.m. with varying throttle positions. Toward the last we had a yoke suction of 5.03 in. of mercury, with the throttle about full-open. At the end of 20 min. of running at that position we opened the throttle wide. The cylinder-head temperature had been 554 deg. fahr. but, when we moved the throttle the very small amount required to make it wide-open, the yoke suction was reduced about 0.03 in. of mercury, the cylinder-head temperature increased to 570 and then to 597 deg. fahr. and preignition started.

R. E. WILSON:—Mr. Ricardo has brought out one very important point in emphasizing the fact that pressure is a more important item than temperature in causing detonation. Others have brought out the same point, but Mr. Ricardo has suggested that the chemist claims that pressure could not influence the rate of a chemical reaction principally. As a chemist, I emphatically disagree with that. It is a well-established law, both from a purely theoretical standpoint and from many practical experiments, that although pressure has no effect on the rate of a reaction in the liquid state, where the molecules cannot be brought much more closely together, the increase of pressure in gases does greatly increase the rate of a reaction by bringing the molecules more closely together. The law has been worked out very carefully and it has been proved that the rate of reaction is proportional to the product of the partial pressures of all the molecules reacting, whatever the initial or slowest step in the reaction is. In a reaction like this we have a great many molecules of oxygen, and a single molecule of fuel. However, the *slow* step in the reaction would probably be to get the first molecule or two of oxygen in. Unfortunately, we do not know what that slow reaction is but, if we assume that two molecules of oxygen and one molecule of fuel must combine, then the rate of reaction would increase approximately as the *cube* of the pressure. In other words, Mr. Ricardo has mentioned that increasing from 4 to 6 atmospheres would mean an increase of 50 per cent in the pressure, but an increase of about 340 per cent in the rate of reaction from a theoretical standpoint, which is a much larger increase than one would expect from temperature. If we add to this the increase we get due to the higher temperature only, and also the increase due to having a smaller quantity of exhaust gases present, both of which are real factors, I think we can explain, almost on a quantitative basis, the speeding up of the rate of flame propagation at the higher pressures. But the pressure itself is probably the most important single factor of those three, although the other two enter also.

THOMAS MIDGLEY, JR.:—The original report of the du Pont de Nemours Co. presented the results of some work that was done in photographing the velocity of flame travel and the influence of pressure. The conclusion it reaches is as follows:

> The investigation of the effect of increased initial pressure proved most unsatisfactory, as this work was attempted before the bomb was made gas-tight through sealing the window by gaskets. The leakage made it impossible to control the pressures accurately and, as a result, good checks could not be obtained. The photographs obtained of the 10 and 15-per cent acetylene-air mixtures, respectively, under initial pressures of 7½, 15 and 30 lb. gage, seem to show approximately a 20-per cent increase in the rate of propagation with an increase of 2 atmospheres in initial pressure, while the arrest in the flame is slightly lowered.

This means the total time in which the whole reaction occurred. The photographs show unmistakably a great rise in the initial rate of combustion due to the effect of the pressure. In further discussion of this point and the interesting conclusions drawn by Mr. Ricardo as to the reason the knock is less at reduced pressures, will Mr. Ricardo explain the behavior of an aviation engine that is, in effect, going up in the air in the altitude chamber? Under those conditions the percentage of the diluent with wide-open throttle is identically the same, irrespective of the altitude, and it is a well-known fact that the detonation dies out with the decrease of the barometric pressure. Also, will Mr. Ricardo give us a better picture of what he believes the phenomena of detonation to be? I believe he has not stated clearly just what he has in mind; I should like him to recapitulate more definitely what his conclusions are with regard to detonation, and state whether what he has said is merely an opinion or whether he has substantiating data. If he has substantiating data, I ask him to present them. He says that, after the combustion proceeds normally for some time, the gas in advance of the flame-front is compressed to a point where it ignites spontaneously and

simultaneously throughout its whole bulk. If this phenomenon does occur, as stated, "spontaneously and simultaneously," how does this set up an explosion wave and, in turn, how can this explosion wave compress the first burned portion to much above the temperature that would be reached by normal combustion?

I do not see the connection between the results obtained from the ignition-investigation device that is described and the internal-combustion engine. Professor Dixon, of the University of Manchester, has done this work in an excellent manner and photographed the behavior of the flame. Those photographs show conclusively that the flame originates at one point, after some little time, and then spreads through the whole mass much as though it had been lit by a spark-plug. In fact, Professor Dixon found nothing to correspond to detonation under those conditions. The difference between this apparatus and the apparatus Professor Dixon used appears to be only from the mechanical standpoint. I fail to understand how conclusions on detonation can be drawn from photographs that fail to show it.

E. R. HEWITT:—I made a large number of experiments for the Bureau of Mines during the war on the premature-ignition point of fuels with some 150 samples of various types of gasoline. The ignition point was determined by pumping the fuel and the proper amount of air into a small, 200-cu. cm. (12.2-cu. in.), bomb. The bomb was then dropped into molten solder. The solder was heated sufficiently to raise the bomb to a predetermined temperature. If the ignition took place then, the explosion was registered by a safety-valve and a gage. By repeating this test two or three times, I could determine the ignition point of any fuel within a few degrees, and there was no possibility of any higher temperature than that determined by the solder when the bomb was dropped in. The conditions were the same as in an engine because the internal section of the bomb was coated with carbon and with oil, as it ordinarily is in an internal-combustion engine. The ignition points varied anywhere from 640 to as high as 720 deg. fahr., that of the usual gasoline being about 670 deg. fahr.

At times, the bomb would not explode. I then drew off the gases through an exhaust-analysis apparatus. To my very great astonishment, I discovered that complete combustion had taken place without any rise of the explosion pressure whatever. I found this would take place in times varying anywhere from 1 up to 8 or 10 min. I then lowered the temperature and found that I could get complete combustion of a mixture of gasoline and air at temperatures as low as 425 deg. fahr. This being an entirely new fact to me, I communicated it to the Bureau of Mines. The chief chemist, Dr. Perdew, verified the experiments that show that these combustions take place at the temperatures as given, and so slowly that there is no rise of pressure. This is exactly the same phenomenon that Mr. Ricardo shows in the diagram in which he gets this flat section where this premature burning takes place before the rise of pressure actually occurs. This seems to me to be a very interesting and very significant phenomenon in detonation. At times I obtained pressures that ran as high as 700 lb. per sq. in., but the usual pressures were about 300 to 500 lb. per sq. in.; so, I obtained detonation in the bomb without any ignition through use of a spark-plug, and the flame wave must have been propagated from all sides at once. There seemed to be no reason the flame should originate at one point any more than any other point.

MR. MIDGLEY:—It appears to me that the drawing of conclusions from the behavior of a bomb of cast iron in regard to what happens inside it is less satisfactory than actually seeing and photographing what takes place, which latter method is the one used by Professor Dixon.

O. C. BERRY:—I am deeply appreciative of the paper presented by Mr. Ricardo. We seldom have a paper that will exert so great an influence on engineering in this Country. Mr. Ricardo has set a striking example for the Society in another respect also. In too many cases the Society is looked upon as an authoritative body, rather than as a forum. We have too much false dignity. We are afraid to express our opinions on a subject unless we feel certain that we are right. The best thinkers maintain a very distinct classification of their ideas. Some things they know for certain; and they have definite ideas about others, with an element of speculation in their conclusions. We ought to descend from any possible pedestal of false dignity and be willing to put before other people the things we have thought about but have not settled, so that they can be discussed. A complete answer will be reached much more quickly than if each fellow thinks about his own problems all alone. I have a great admiration for the man who has sufficient sporting spirit to put before the thinking men of the Country ideas that he himself recognizes are only partly worked-out. I have a great respect for Mr. Ricardo in that he has done this in connection with turbulence; he has admitted to all of us that his conclusions are not complete and that he stands ready to change his ideas somewhat on the subject of the effect of turbulence on detonation. The presentation of a paper of this kind is the finest piece of work that a man can do. I think it should be emulated to a greater extent by the members of the Society.

Mr. Ricardo's paper has again brought to my mind the fact that we ought to come to a standard way of computing engineering data for presentation in papers of this kind. In reading this paper I have found it necessary to recompute nearly all of the results on a different basis so as to make them comparable with my own data. The English base their computations almost entirely upon indicated horsepower, indicated mean effective pressure and the lower heat value of the fuel. In this country many of us base our computations and our lines of thought upon brake horsepower, brake mean effective pressure and the calorimeter or higher heat value of the fuel. It may not matter which of these methods we choose as being correct, but it appears to me that engineers ought to decide upon either one or the other to be used in connection with their public records.

There is a valid reason in the mind of the American engineer for basing computation upon brake horsepower and brake mean effective pressure, in that these are values we all have. Some of us cannot obtain the indicated horsepower very accurately. I have tried to obtain the friction horsepower of an engine by a number of different methods, but I cannot make the results check as closely as I would like. From a theoretical and an analytical viewpoint it is valuable to know the indicated horsepower developed by an engine, but still I feel that there is some valid reason back of the desire of the American engineer to express his results in brake horsepower when presenting them for the consideration of other American engineers.

Mr. Ricardo speaks of the results of preheating the fuel as being the same in the three cases of (*a*) preheating the air that enters the carbureter, (*b*) heating the mixture through contact with the hot valves and cylinder walls and (*c*) heating the mixture through admixture with the hot residual exhaust-products in the cylinder

clearance-space. Properly interpreted, the statement is all right, but an engineer who is trying to make a six or an eight-cylinder engine distribute properly is in great danger of misreading it. The carbureter engineer is not primarily interested in thermodynamic considerations. He uses heat because it enables him to get better distribution and better combustion. If proper distribution is obtained by heating the air entering the carbureter, very high temperatures are required and the power of the engine is reduced correspondingly. Satisfactory results can be obtained with much lower mixture-temperatures if a good hot-spot is used.

Mr. Ricardo's idea of measuring the amount of air used in getting the combustion efficiency of the engine is a line of thought that we have not been making enough use of in this Country. The point is to make it possible to distinguish between differences in carburetion and manifold distribution, on the one hand, and fundamental differences in engine performance, on the other hand. However, it seems to me that the heat liberated per pound of air used should be for full power, rather than for maximum-efficiency conditions. Each pound of air represents the liberation of a greater amount of heat under full-power conditions and, since the engine is actually running under these conditions, it should be charged-up with all of this heat.

CHAIRMAN CRANE:—Mr. Berry mentioned the fact that Mr. Ricardo has admitted that some of his earlier conclusions regarding detonation and its relation with turbulence were not correct. I am always much inclined to accept the evidence of a man who does not claim to be more than 99-per cent right; the man who is 100-per cent right in his own estimation is considerably too good to be true. On the other hand, we have the man who is never wrong, and never being wrong is different from always being right; we recognize that. The man who is never wrong is the man who never arrives at a conclusion until it is supplied by the undertaker.

NEIL MACCOULL:—Approximately what percentages of exhaust gases are present in the combustible mixture at the point where minimum fuel-consumption is shown in Fig. 11 and also at the extreme right of the chart where the compression-ratio is 7½ to 1? The statement is made in regard to piston experiments that the leakage of gas past the piston was measured, but no results are given. Was the leakage measured for all conditions of pressure and temperature and, if a leakage was found to exist under all conditions, how did it vary with the pressure and the possible viscosity of the oil? What was the viscosity of the oil that was used when measuring the piston-friction results shown in Figs. 25 and 26?

HERBERT CHASE:—Will Mr. Ricardo tell what was done in connection with the measurement of the spark-advance, or to determine the effect of the spark-advance upon detonation? Experiments made at the Bureau of Standards have shown clearly that the spark-advance has a very marked effect upon detonation under various conditions, and that this condition should be clearly stated in giving data regarding detonation. What means were used for determining when detonation occurred and when it did not occur? Was a listening test depended upon or were indicator-cards or other means used?

One of the most interesting portions of Mr. Ricardo's paper to me is his data in regard to the stratified or localized charge. The engine used in that type of work is frequently referred to in this Country as a constant-compression engine. A number of persons are experimenting with these engines in this Country to-day. It would be very desirable if these gentlemen would give some data that they have secured as a result of these tests, for comparison with the tests that Mr. Ricardo has reported upon.

STRATIFIED-CHARGE ENGINES

R. W. A. BREWER:—Is Mr. Ricardo's implied condemnation of engines using a stratified charge based on the one type of engine illustrated in his paper, or upon general conclusions of stratified-charge engines?

CHAIRMAN CRANE:—The paper as I read it did not strike me in any way as implying any condemnation of a stratified-charge engine. It simply states the fact known to all of us that the stratified charge holds immense possibilities, but that satisfactory conditions of operation are difficult to reach and that it is not so easy to accomplish through a wide range of powers as it appeared to be at first. I think all will agree that this is a fair reading of the paper and that it is far from being a criticism of the stratified-charge engine.

MR. BREWER:—Referring to the portion of Mr. Tizard's conclusions given in Mr. Ricardo's paper where it is stated that the "rate of burning increases very rapidly with a slight increase of the flame temperature, and whether it will prove sufficiently rapid to produce detonation depends upon the ratio between the rate of evolution of heat by the burning mixture and the rate of heat loss," it appears that those two points govern the whole operation of the engine as regards design from a non-detonation viewpoint and I would like to have some further information on that conclusion.

L. H. POMEROY:—What are Mr. Ricardo's views on the question of carbonization as affecting detonation? It seems obvious that carbonization produces the effect of increasing the temperature of the mixture and also of increasing the compression. It is well known that engines that will run without detonation when clean will show marked detonation effects when carbonized, and it will be interesting to learn whether Mr. Ricardo's experiments have thrown any light on the real effects arising from carbonization. If it is the increased temperature that causes detonation, it seems to follow that there must be some connection between the heat loss during compression and detonation that might make Mr. Ricardo's results not necessarily apply to engines with small cylinders where the heat loss is considerable, particularly at low speeds.

CHAIRMAN CRANE:—I think that all who have had experience with overhauling cars have noticed the fact that, after completely cleaning the cylinders and reassembling the engine, a very considerable increase in the amount of heat being taken care of by the radiator is apparent when the car goes back on the road. That increased heat comes from the fact that we have much cleaner surfaces where the heat is being generated originally.

SLIPPER ALUMINUM PISTONS

G. A. GREEN:—In September 1919 the Fifth Avenue Coach Co. made up a set of Ricardo slipper-type aluminum-pistons. These were subjected to dynamometer and road tests. As a result, some valuable information has been gathered, and it is thought that these data are of sufficient interest to warrant presentation. Fig. 37 shows in a general way the construction of Ricardo pistons. Comparing this design with the conventional heavy-ribbed four-ring aluminum piston used by us, the following points are of particular interest:

(1) There is twice the amount of metal at the crown and back of the rings; ⅜ in. as compared with 3/16 in.
(2) Wristpin bosses are rigidly connected to the crown with 5/16-in. ribs

FIG. 37—VIEW OF THE RICARDO SLIPPER ALUMINUM PISTON

(3) Rings are only one-half the width; ⅛ in. as compared with ¼ in. There are three instead of four rings
(4) Slippers are separated from the head by a deep circular cut below the bottom ring. Slippers and head are connected through the ribs carrying wristpin bosses. Because of this separation, it is possible to reduce slipper clearance to the minimum since a considerable amount of the head heat is dissipated before it can reach the slippers
(5) Frictional surface is less than one-half; 17.004 sq. in. as compared with 37.330 sq. in.
(6) Wristpin is well secured by a ¼-in. bolt, nut, two light washers and cotter. The possibility of its loosening-up and scoring the sleeves is remote. This is a very important point
(7) Weight of piston, wristpin and rings is 36.5 oz. as compared with 51 oz.

A standard engine was equipped with Ricardo pistons, put through the usual running-in procedure, and then tested on our dynamometer as follows:

(1) Full throttle, 700 to 1400 r.p.m.; increments of 100 r.p.m. Data taken as to brake-loads and fuel-consumption
(2) Friction horsepower, wide-open throttle, 700 to 1400 r.p.m.; increments of 100 r.p.m. Data taken as to torque required to turn the engine over

On completion of the above tests, the slipper pistons were removed and replaced with our standard type; then the tests were duplicated. Analyzing the results obtained from these tests, it was found that

(1) From the standpoint of mechanical efficiency, there was a difference of 6 per cent in favor of the Ricardo pistons throughout the entire speed-range, the curves being practically parallel
(2) A very slight superiority was shown in regard to fuel-consumption. The difference was, however, almost negligible
(3) The torque developed was higher throughout the entire speed-range, the average difference being 6 per cent. At the peak of the curve, at 700 r.p.m., the amount in favor of the Ricardo pistons was 9 per cent.
(4) The amount of power required to turn the engine over, or friction horsepower, averaged 20.9 per cent less throughout the entire speed-range

Obviously, these results warranted further tests under actual service conditions; so the Ricardo pistons were replaced and the engine was assembled in one of our buses. The road tests commenced in October 1919 and continued until November 1921, when the pistons were removed on account of wear having developed at practically all points. During this period the vehicle covered a service mileage of 65,970 miles. In view of the comparatively short space of time available it was not found possible to prepare complete data as to the performance of the pistons, but the following figures representing the consumption of gasoline and oil from March 8, 1921, to Nov. 4, 1921, are indicative:

Mileage	24,294
Miles per United States gallon of gasoline	7.93
Miles per United States gallon of oil	419

Assuming the use of the Imperial gallon, these figures would be increased to 9.51 and 503 miles per gal. respectively. This can be considered as an exceedingly good

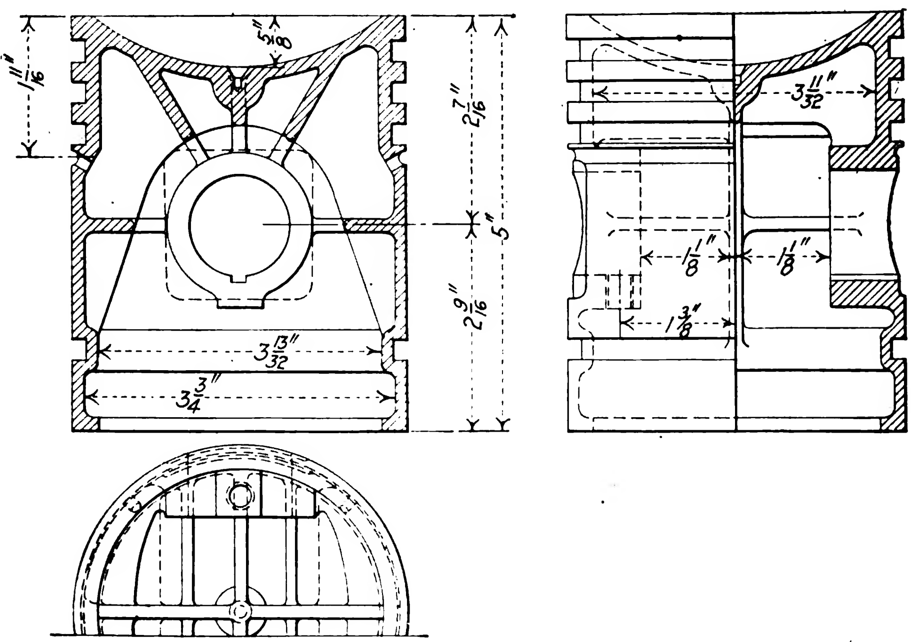


FIG. 38—PLAN VIEW AND ELEVATIONS PARTLY IN SECTION OF THE STANDARD PISTON USED BY THE FIFTH AVENUE COACH CO.

showing from a fuel standpoint, and represents approximately 54 ton-miles per United States gallon throughout the entire period. On completion of the test the engine was stripped-down and the pistons, sleeves and cylinder-heads examined from the standpoint of lubrication. The following points were observed:

(1) There was almost perfect inner sleeve lubrication
(2) The slippers and surfaces between the rings were clean and free from carbon
(3) There was a rather heavy deposit of carbon on the under side of the heads
(4) There was a very slight deposit of granular carbon on top of the pistons; the heaviest deposit was nearest the exhaust-ports
(5) There was practically no carbon deposit on the junk-heads
(6) The junk-rings were in excellent condition, showing nearly 100 per cent bearing surface and perfect lubrication

The pistons and rings were then carefully gaged to determine the amount of wear. The results of these measurements are shown in Table 11.

TABLE 11—WEAR OF PISTONS AND PISTON-RINGS

Location	Wear, in.
Above Top Ring	0.0060
Between Rings Nos. 1 and 2	0.0070
Between Rings Nos. 2 and 3	0.0065
Top of Slipper	0.0130
Bottom of Slipper	0.0100
Diameter of Rings	0.0015
Width of Rings	0.0015
No. 1 Ring Groove	0.0110
No. 2 Ring Groove	0.0060
No. 3 Ring Groove	0.0030

Analyzing these figures, it will be noted that

(1) The wear between the rings is fairly constant and averages 0.0065 in.
(2) Wear at slipper is 0.003 in. greater at the top than at the bottom. The average wear is 0.0115 in. This, plus the necessary clearance, was sufficient to produce considerable noise
(3) Wear at outside diameter of rings, 0.015 in., is not unreasonable considering the mileage
(4) Wear at sides of rings, 0.00075 in. per side, is not unreasonable considering the mileage
(5) It is interesting to note the progressive wear of ring grooves, 0.003 to 0.011 in. The top groove shows up worst

Due to the theoretical advantages of this class of piston, one would naturally expect decreased vibration, piston slap, friction horsepower and fuel-consumption, and less wear-and-tear generally; in short, a better all-around engine performance. In actual practice, all of these points were proved. At the beginning, it was thought that perhaps considerable trouble might be experienced from rapid wear and high oil-consumption. However, this fear proved to be groundless.

Answering the points raised by Mr. Crane, there are shown in Fig. 38 various views of our standard piston. Judging by the experimental set referred to in this test, there should be very little difference between these pistons from the standpoint of wear but, of course, one instance does not prove this. As a matter of fact, there seems no good reason why the Ricardo piston should not have equal wearing properties. The same remarks apply insofar as cylinder wear is concerned. Of course, it must be remembered that with Knight engines the inside diameter of the inner sleeve is the only point at which wear occurs as a result of piston movement.

Perhaps it is scarcely necessary for me to enlarge upon the great value of properly carried out research work. Many of us have learned slowly and painfully that lasting success, mechanically speaking, can be attained only when there is a proper coordination of theory and practice. I am sure we are all agreed on this subject: the establishment of the Society's Research Department represents the stamp of official approval of this. In our own research department we have collected much very useful information, and we are prepared in practically all cases to place our records at the disposal of members of the Society. It seems to us that a broad-gage policy such as this must in the long run be helpful, since it will foster a spirit of practical cooperation that should be of benefit to the industry. Unquestionably Mr. Ricardo's paper represents a most valuable contribution to the industry.

E. A. SPERRY:—This paper covers but a fraction of Mr. Ricardo's contributions to this wonderful art that appear from time to time. Inasmuch as the subject is research and research has to do with the future, why should we not take one other aspect of the future with regard to detonation? Here is an example where automotive engineers have apparently taken to the woods in trying to dodge detonation. As a matter of fact, how do we know that Nature is not trying to hand us something advantageous in detonation? Why not seek to harness it? One absolute fact has been established; it is that we know we get higher efficiency when we get detonation. That has been the result of observations on both sides of the Atlantic. Why do we not design an engine around the proposition of detonation? Why dodge it? Think for a moment what this would accomplish. It would relieve us entirely of all these troublesome questions of stratification and all of this perplexing matter of fuels. What would we care about fuels in such a case? Not only could we use the present-day gasoline, but we could use kerosene and go on to the much cheaper fuels. Engines are running today on fuels that are quoted on the present market at $1.22 per bbl., with clear and odorless exhaust. Let the fuel detonate; the more it detonates the more efficiency it provides. That would relieve us entirely of compression-ratio limitations. We then would be able to increase the compression and get the higher efficiencies to which we are entitled. It would relieve us of carbon deposits by permitting us to increase combustion temperatures to a point at which no carbon is ever deposited. It would relieve us of all the trouble due to carbon monoxide, since not a particle of that gas is formed when fuels are burned at high temperature. Thousands of Diesel engines work at these high temperatures without any trouble. Steam engineers now seek Diesel-engine jobs on ships. They find that it is easier than steam-engine work, with its boilers and endless auxiliaries.

H. S. MCDEWELL:—All technical and scientific publications appearing in Great Britain seem to attach considerable significance to dissociation. About what percentage of influence does dissociation have in the results of Tizard and Pye? Assuming a maximum combustion temperature, which Mr. Ricardo has mentioned in a previous paper as being 2480 deg. cent. (4496 deg. fahr.), only about 0.2 per cent of the weight of the hydrogen present in a normal gasoline would be dissociated. This would correspond to about 0.6 per cent of the heat of combustion of the fuel; consequently, that does not seem to be a very material effect. How closely do Tizard

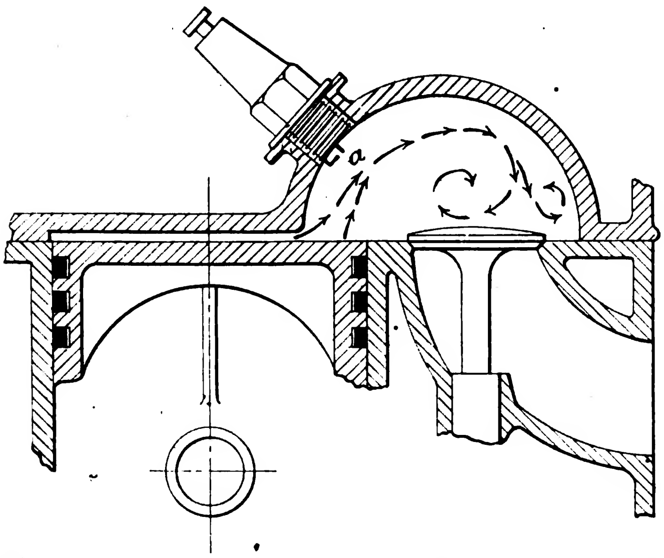


Fig. 39—Locating the Spark-Plug at *a* Was Supposed to Give the Maximum Turbulence in a Valve-in-Head Engine

and Pye's results check with these figures? Does the good luck that Mr. Ricardo mentions in connection with his efforts with a stratified-charge engine also extend to his supercharging engine?

H. L. Horning:—Mr Ricardo's paper cannot be absorbed within the short time we have had to read it. We have been quite unfair in asking him to expose his innermost thoughts on the entire range of subjects in the experimental development of the internal-combustion en-

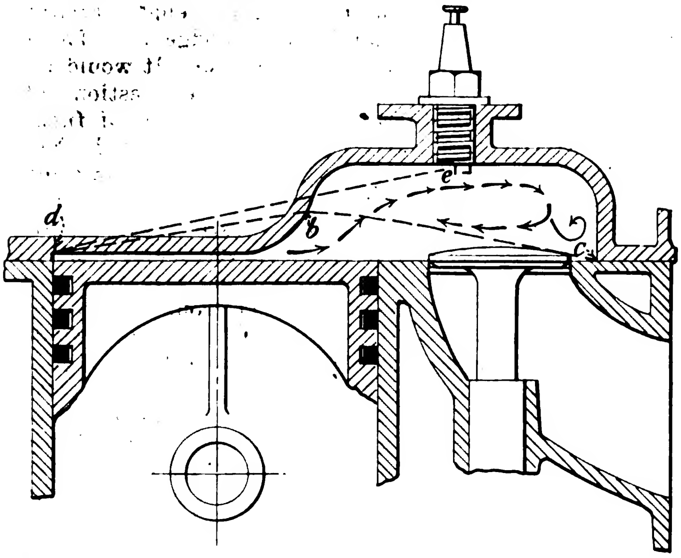


Fig. 40—A Form of Combustion-Chamber That Gave Violent Detonation

gine. A man can be an expert on one or two phases of any subject, but when we ask him to cover all of the details of a general subject, it becomes a very difficult task. Measured by that standard, he has met our expectation marvelously.

In trying to trace the relationship between detonation and turbulence in the Ricardo shape of combustion-chamber, J. B. Fisher, the chief engineer of the company with which I am associated, and I agreed that if we located a spark-plug at the place of maximum turbulence, we would certainly kill all detonation. According to our best information, we located the spark-plug as shown at *a* in Fig. 39, but detonation continued.

Mr. Ricardo's most effective combustion-chamber is the form shown in Fig. 40. We used this form and the engine detonated violently. Mr. Fisher called attention to the fact that right at the point *b*, as the piston comes up, there must be a terrible movement of gases. There was no other way to get more effective turbulence because, at the moment the spark jumped, we were getting the most violent passage of the gases. We located the spark-plug at *b*, but that did not help matters except that it showed by that simple experiment the correctness of what Mr. Ricardo has told us. In his paper Mr. Ricardo

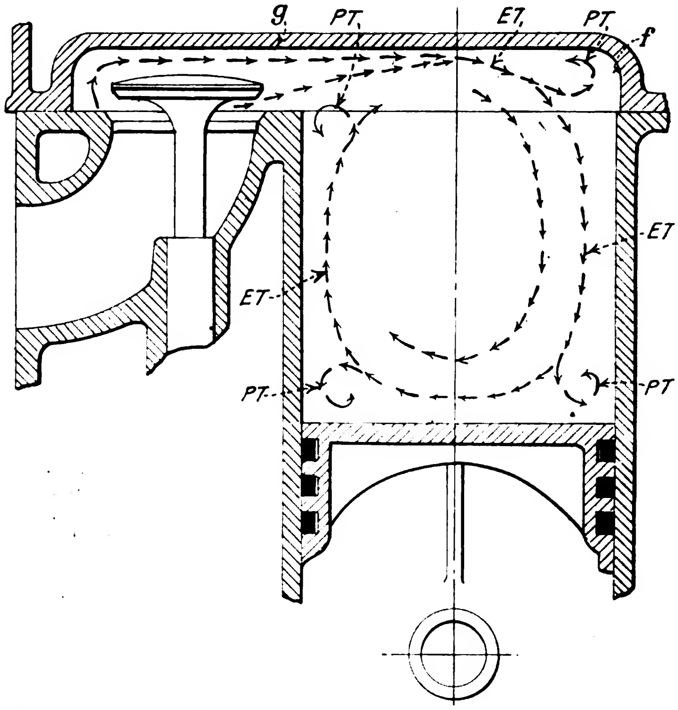


Fig. 41—An Ordinary Type of L-Head Combustion-Chamber Showing Two Possible Locations for the Spark-Plug

has called attention to the fact that it is the maximum distance *bc* or *de* that almost certainly seems to be the controlling factor. I have talked with Mr. Ricardo and

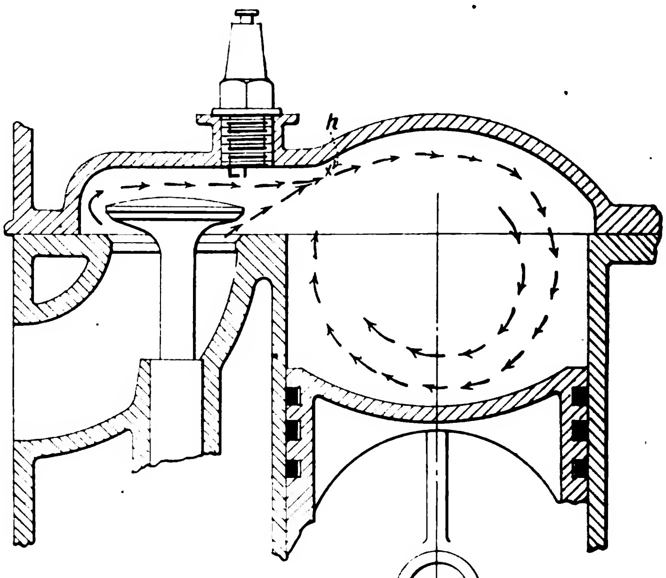


Fig. 42—Combustion-Chamber of the Mark Webber Tank Engine Designed by Ricardo in Which Locating the Spark at *h* Did Not Give Good Results

we agree that there is one other factor; it is the tendency to detonate when the spark-plug is opposite to a pocket. I wish to call attention to the fact that if the spark-plug is located at *f*, as in Fig. 41, that would obviously increase the distance and the spark-plug would be opposite the valve-pocket, but to locate it at *g* would decrease the distance and the spark-plug would be within the pocket.

Mr. Ricardo has referred in his paper to remarks that I made in my paper on Turbulence in regard to his Mark Webber engine. We made a test with the spark-plug located as at *h* in Fig. 42, and could not get good results. I said in my paper that Mr. Ricardo seemed to get good results, but he says now that they had trouble and had to move the spark-plug to the location shown at *h* in Fig. 42. Those two factors constitute the evidence in support of his statement that turbulence does not affect detonation directly.

F. E. Moskovics:—If the members of the Society will take the paper presented by Mr. Ricardo as a mental stimulus in addition to the value of the actual data it contains and the original research it discloses, they will derive the maximum benefit from it. I trust and believe that this paper is only the beginning of a discussion that will be general and of long duration. This is the stuff that the advancements in science are born of, and in that regard Mr. Ricardo's paper is peculiarly timely and forceful. May we at the same time convey to him the thought that, in the discussion, however freely views may be discussed, nothing personal is intended; it represents only the true zeal of the scientist in reaching the goal. Mr. Chairman, in view of the peculiar timeliness of Mr. Ricardo's paper, I move that the members of the Society express, by rising, a vote of thanks to the distinguished visitor, Mr. Ricardo, for traveling so far and going to such pains to present this remarkable paper to the Society. [A rising vote of thanks was accorded Mr. Ricardo, accompanied by hearty applause.]

Chairman Crane:—Having thanked Mr. Ricardo for his paper, we now incur a further obligation by requesting him to answer some of the questions that have been asked.

Mr. Ricardo:—Thank you very much for showing so much interest in my paper and for the very interesting discussion.

Mr. Grimes raised a point regarding the value of the exhaust products in a kerosene engine. I am not quite clear what exactly he has in mind but, rightly or wrongly, I understood him to mean that he had obtained equally good results by using a lower compression-ratio. Insofar as power output is concerned, I fully agree; because, from this point of view, there is very little difference. With a low compression-ratio you retain a greater proportion of exhaust products within the cylinder; with a higher compression some additional products must be added to keep the flame-temperature down. These additional exhaust-products reduce the volumetric efficiency so that the increase of thermal efficiency due to the higher compression and the loss of volumetric efficiency due to the diluent just about balance. The power output remains therefore the same whether the compression be high or low within reasonable limits, of course. The thermal efficiency, however, is dependent directly upon the compression-ratio and from this point of view the use of additional exhaust-products and a high compression are preferable up to a certain point. I gave the results of some investigations on these lines in Fig. 11 of my paper. The instance Mr. Grimes cites, of an engine running steadily at 2250 r.p.m. at nearly full throttle and failing at a very slight increase in throttle-opening, is very interesting as showing that a very slight addition to the charge and therefore to the flame-temperature will bring about detonation, increased wall-temperature and subsequent preignition. This is just what one would expect.

Mr. Wilson raises the question of the influence of pressure on the rate of burning. I need hardly say that his remarks are of special interest to me. I had always clung to the conviction, being no chemist at all, that the pressure plays much the most important part, but I was rather shaken out of that idea by our chemists in England. I gather from Mr. Wilson, who, I recognize, speaks very authoritatively, that it may play a very significant part indeed. This being so, all I can say is that I am very pleased to hear it because it supports my own feeling which I had rather surrendered on account of the criticism leveled against it. I do not think that it affects Tizard's more recent theory except, perhaps, in a quantitative degree.

Mr. Midgley raises exactly the same point; that the pressure does play a part. I am very glad to hear this view supported, for I am still inclined to believe that it does. The altitude question has always been my own pet argument in support of the pressure theory; so we are in complete agreement there.

With regard to Professor Dixon's results, I agree that results yielding photographs as his did are very much more valuable. I wish we could have taken photographs in this case, but the experiments were carried out on a small apparatus where the cooling losses were playing a very serious, if not overwhelming, part. Mr. Tizard was asked by the Board of Industrial Research to go carefully into these results and see if it was not worthwhile trying the experiments on a larger scale; so we used a cylinder which was precisely the same size as that of the variable-compression engine with which we were carrying on the other tests. That is really the reason for it. It became very apparent early in the tests that the rate of dissipation of heat was playing a very vital part.

Mr. Midgley asked if I would give the intermediate stages between the results from the compression machine and the conclusions on detonation deduced from them. I wish I could. I had hoped before today to be able to do so, but those deductions form the subject of a paper that Mr. Tizard will publish very shortly; therefore, I must ask that his paper be accepted as the intermediate stage when it appears. I had hoped and expected that Tizard's deductions would have been published before now, when I should have been free to quote them.

Mr. Midgley further criticizes, and very justly too, the use of the words: "spontaneously and simultaneously." These words must of course be interpreted as relative. In this connection I should like to say that I had no opportunity to correct the preprint of my paper and that there are, I fear, a number of errors in it. In the copy I read from, the word "nearly" was introduced and I was careful to emphasize this when reading the paper. As I interpret Dr. Dixon's photographs, it seems to me that he did find almost exactly what is generally meant by detonation, namely, an extremely abrupt change from a normal rate of burning to that of an intensely rapid one.

Mr. Hewitt gave some very interesting details of his experiments with a bomb. His results are almost exactly the same as were obtained under sudden adiabatic compression and are therefore particularly interesting to me. We also had cases where combustion was complete without any appreciable rise in pressure, but I do not think

there is anything surprising in this. We assume that the rate of combustion is a function of temperature, but that it rises very rapidly with increase of temperature. Combustion undoubtedly takes place at comparatively low temperatures, but the rate is then very slow indeed.

Mr. Berry mentioned the advisability of expressing results in terms of brake horsepower, rather than of indicated horsepower. I have adhered consistently to the indicated performance for the last 2 or 3 years. I quite agree that there is a possible error in determining indicated horsepower; but, by adding up the friction losses obtained in various ways and by various cross-checks, I think one can obtain indicated horsepower pretty closely, at all events in the case of engines with which I have had wide experience. I prefer it, because the results expressed in indicated horsepower are applicable to any case; whereas results in brake horsepower are really peculiar to the engine one is using. If I had expressed the results in terms of brake horsepower in our particular variable-compression engines, I should have given rather scandalously good results because the mechanical efficiency of that engine is exceptionally high. It is a ball-bearing job throughout. I particularly wanted to avoid that. Those results would not be applicable to other engines.

Mr. Berry refers to the division I made as to the sources from which the entering charge receives heat. I ought perhaps to have emphasized that I was referring only to the question of volumetric efficiency. Only the first of the three sources is of any interest from the point of view of distribution; the others may, I think, be regarded as constant. With regard to air-measurement tests and the use of them for deducing the efficiency, I think that the point he raised is dealt with in Appendix 3. I should like to take this opportunity of thanking Mr. Berry for his very flattering and sympathetic remarks.

Mr. MacCoull asked for figures as to the percentage of exhaust products used in connection with Fig. 11. I cannot quote it exactly because it was not measured directly. We had no means of measuring it at that time, but a fair estimation can be obtained from the difference between the mean effective pressure obtained with and without; that is, between the mean effective pressure obtained with pure benzene and the mean effective pressure obtained with gasoline and exhaust products. That is only a rough approximation because, of course, the efficiency was not the same in the two cases. Without going into great detail, I should think that, if the ratio of mean effective pressure is taken in the two cases and a further allowance of 50 per cent for the drop in efficiency is made, this will approximate the proportion of exhaust products.

With regard to leakage of gases and the quality of the oil used, I am not, I regret to say, provided with any figures. We have made no leakage tests for a long time; in fact, not since the war. We used Price's gas-engine oil in all cases. It is an almost uniform standard oil in England that we used to employ throughout all our testing; but I have no figures, I am sorry to say, as to its viscosity. I certainly found that the viscosity of the oil played a very important part in piston gas-leakage.

Mr. Chase inquires about the degree of spark-advance used in determining detonation. I think that is a very important point. We have always defined the detonation point as the highest compression-ratio at which one can advance the spark without detonation until the torque definitely falls. For example, at a compression-ratio of 5 to 1 and with average gasoline, the maximum torque is obtained with an ignition advance of 32 deg. before top-center. If we advance to, say, 40 deg. before top-center with a mixture giving complete combustion, the torque falls considerably and, if we can get over to that point without detonation, we consider we are within the range with every change in compression-ratio. The whole available range of ignition timing is explored in this manner.

As regards the method of detecting detonation, we have tried various devices, including the optical indicator; but, in the case of this particular engine, we have found the listening test a very sensitive one, for the cylinder appears to be exceptionally resonant and detonation is very definite. We have tried with various observers on a standard fuel and three different observers working independently and at different times have determined the maximum compression-ratio as being 4.83, 4.85 and 4.85 to 1 respectively. Again, in this engine, detonation, if allowed to persist, very soon breaks down into preignition. It is only since I have been here that I have heard for the first time of the very ingenious device which Mr. Midgley has been using and which appeals to me very strongly.

Mr. Brewer suggested that I had rather damned the stratified charge. I am sorry if he got that impression, because it is not the one I intended to convey. I have always been, and I am still, a great enthusiast for stratified charge. I did not want to paint it in too rosy colors, because I have had some very unfortunate experiences with it, but I certainly think it has a great future.

Mr. Pomeroy raised the question of the effect on detonation of carbon on the piston. It is rather difficult to give what experience we have in any quantitative terms, but the effect of carbon on any part of the combustion-chamber is to delay the rate of dissipation of heat. This is very conspicuous in the case of the detonation or compression machine. There, if one had bad detonation or if one worked with a very rich mixture, a thin coating of carbon would form on the walls with the result that the next experiments would be very erratic indeed and show a large difference in the temperature coefficient. It was necessary, therefore, always to clean and wipe out the cylinder thoroughly. As regards quantitative terms, in the case of the variable-compression engine, when it is quite clean, it will run on a straight paraffin gasoline with a compression-ratio of 4.85 to 1. When it has run for about 3 months at an average of 5 or 6 hr. per day, that ratio has dropped to about 4.75 to 1. We have to make a correction; we retest from time to time on it. After about 3 months the engine is taken-down and recarbonated.

Mr. Green gave some data that are very interesting to me on the piston he has been using. I have nothing to add except that his contribution to the discussion is very gratifying indeed, and I am most grateful to him for the trouble he has taken.

Mr. Sperry, as I understand him, was putting forward a strong plea for the Diesel or high-compression self-igniting engine for automotive work. While I sympathize with all his arguments, I feel that this is rather a long-distance shot as yet. I cannot claim a great deal of experience. I was watching the British Admiralty's experience on Diesel work throughout the war. It seemed to me that considerable advances were gained, but there is still a very long way to go before we can consider that as a possibility. I feel that the use of a stratified charge is an intermediate measure. It is, in a sense, getting a Diesel cycle, although it does not, of course, permit of

(*Concluded on page* 347)

The Tractor Market

By J. S. CLAPPER[1] MINNEAPOLIS SECTION PAPER

AFTER stating that the tractor industry has reached the most critical period in its history and that the farmer has been quicker to appreciate the possibilities of applying mechanical power to farming than the tractor builder, in that the latter has held to producing a one-purpose machine instead of analyzing farm demands and producing a machine adaptable to them, the author outlines diversified-farming requirements and supplements this with statistical quotations from a Government report that indicate the character and exent of the market for tractors and advocates a machine suitable for all farm purposes.

Farm-implement finance is considered briefly, and tractor suitability for specific purposes is commented upon, inclusive of statements by representative tractor distributors.

THIS subject is of such importance and covers such wide possibilities for argument that, in trying to analyze the conditions that have affected the tractor market, I may subject myself to criticism from some tractor builders. This is especially true when I say that the tractor business has reached its peak and that it will be a long time before the farmer can be persuaded to accept the present type of machine and to do his part in motorizing his farm, unless some changes are made by the builders, and that very quickly. I will not attempt to tell how tractors should be marketed, but shall mention some of the vital things that I believe are affecting the demand.

There is too wide a gap between what the builder receives for his product and what the farmer is compelled to pay. The former does not receive enough money to meet, later on, the demands made by the selling organization and the user. My opinion is that the tractor industry has reached the most critical period in its history and whether it goes forward or backward depends entirely upon the producer and the sales organization through which all products must find an outlet. We must all admit that the tractor business is in a state of depression, but I do not know how many of the companies have made the proper analysis of the conditions and are willing to apply the proper remedy. I do know that some of the large manufacturers of accessories necessary to the production of tractors, as well as the managers of some of the most prominent advertising mediums, are fully awake to the situation and are trying to place some of the actual facts before the builders. We all know that it takes more courage to correct a mistake than it does to suffer for years on account of it. From observation, I am thoroughly convinced that the farmers have been quicker to appreciate the possibilities of applying mechanical power to their farm operations than the manufacturer. I base this statement upon the fact that the latter, as a whole, have held to a "one-purpose" machine, expecting the farmer to arrange his work to fit the machine instead of analyzing the farmer's requirements and supplying him with a machine that will fit his farm work. I think this has resulted mostly from following the old custom of designing and perfecting a machine or implement to do one certain class of work.

In the early days of the development of the tractor, only two operations were considered; first, the breaking-up of the large acreage of prairie sod and, second, the pulling of separators for threshing or the use of the tractor for providing belt-power. I often wonder if the manufacturer of farm implements has ever given the farmer the credit to which he is entitled for the part he has played in developing and perfecting every farm implement that has been put on the market. It was the farmer who first discovered that disc-harrows, a battery of seeders or grain-binders could be pulled successfully by a tractor.

DIVERSIFIED-FARMING REQUIREMENTS

No one who has any knowledge of farming with horses in the section devoted principally to grain and has seen horses replaced by a well-designed tractor can question its adaptability to such service and the wonderful saving it effects. It was in this field that the present type of tractor was developed and found such a ready market; but this field is small in comparison to the entire acreage of crops that must be cultivated. A tractor designed so that it can be used for plowing, preparing the seed-bed, planting and cultivating will meet all of the conditions and requirements in the diversified-farming sections, and it will prove more efficient and economical than horses. There are five prospective purchasers for a machine of this type where there is one purchaser for the one-purpose tractor.

Government statistics show that there is a total annual loss of $232,644,000 on account of weeds in corn, cotton, potatoes, beans, sugar beets, sweet potatoes and soy beans, due to lack of proper cultivation. It has been my firm conviction for several years that it is entirely practicable and feasible for engineers and builders to analyze the farmer's requirements correctly and hold their design and actual accomplishments to fit the work to be done. It has been demonstrated thoroughly that a machine can be made strong enough and have ample power to handle two plows, but still be light enough for all classes of row-crop cultivation from sugar beets to corn. However, the engineer or company that has not had actual experience in the cultivating of row crops should study every operation and become thoroughly familiar with the requirements first.

The most difficult operations in farming are the first and second cultivations of the tender plants and, unless the operator has an entirely unobstructed view of the rows and the machine has enough flexibility that the cultivating teeth of the shovels will respond promptly to every controlling movement of the operator, good clean cultivation is not possible without injury to the plants. Unless we can give the farmer a machine capable of doing equally as good cultivating, one that is easier and more economical to operate and will perform the work faster than it can be done with horses with less effort on the farmer's part, we have but a slight basis of argument to persuade him that he should motorize his farm.

What argument can a salesman present to the farmer today that will persuade the latter to invest in a machine,

[1] M.S.A.E.—President, Toro Motor Co., Minneapolis.

TABLE 1—FARMS OPERATED BY THE TRACTOR IN 1920

State	Per Cent
South Dakota	16
North Dakota	15
Montana	12
California	10
Kansas	10
Illinois	9
Iowa	9

at the present prices of horses and feed, when the records show that tractors have replaced only 20 to 22 per cent of the horses? What would be the result if another salesman could show this same farmer a machine so adaptable to his work that it would actually replace 75 to 80 per cent of his horses and 40 to 60 per cent of his surplus labor, if the price of the machine were within his reach? The machine must be capable of ready adaptability to the different classes of work and be sold at a price within the farmer's purchasing power, which has now reached the lowest point in his experience. The all-purpose machine designed so that it can be adapted easily to more different kinds of work on the farm is entirely practical and will be accepted readily by the farmer who is searching for improved and economical methods. No one engaged in the tractor business is more optimistic over the possibilities of power farming or the success of motorizing the farm than I am, but we must first motorize our ideas, our factories and our own products before we can expect the farmer to motorize his farm.

TABLE 2—ACREAGE OF THE FOUR PRINCIPAL CROPS

Crop	1910 Acreage	1919 Acreage	Difference, acres
Corn	69,000,000	63,000,000	6,000,000 (Decrease)
Wheat	32,000,000	53,000,000	21,000,000 (Increase)
Oats	27,000,000	31,000,000	4,000,000 (Increase)
Cotton	14,000,000	15,000,000	1,000,000 (Increase)

STATISTICAL CONSIDERATION

On Jan. 1, 1920, the Department of Agriculture reported a total of 246,000 tractors on the farms in the United States or about one tractor for every 28 farms. The States showing the highest percentages of all farms reporting tractors are listed in Table 1.

The complete report covering the year 1920 gives the total valuation of all farm equipment produced in that year as $537,000,000. The report shows further that 203,000 tractors were constructed in 1920. Their value was $193,000,000 or more than one-third of that of the total of farm equipment.

ACREAGE OF THE FOUR PRINCIPAL CROPS

Let us consider the acreage of the four principal crops for 10 years as shown by the Government statistics given in Table 2.

These figures indicate that there has not been a very great increase in the acreage of the four principal crops during this period, but other statistics show that the value of farm-implement equipment during the same period increased 185 per cent. It has been the custom of the Department of Agriculture to tabulate each season the totals of 22 of the principal crops, one-half of which are row crops requiring cultivation. The figures in Table 3 are given by States, indicating the difference in valuation of these 22 crops produced in 1919 and 1920.

TABLE 3—PRINCIPAL CROPS OF 1919 AND 1920

State	Decrease in Valuation of 22 Crops	Decrease in Valuation of Total Crop
New York	$23,000,000	$32,000,000
Pennsylvania	50,000,000	77,000,000
Maryland	18,000,000	23,000,000
New Jersey	3,000,000	6,000,000
Ohio	173,000,000	199,000,000
Illinois	344,000,000	400,000,000
Iowa	263,000,000	450,000,000
Minnesota	197,000,000	212,000,000

The loss in the Middle and Western States is much larger than in the New England States. This is an indication of the shrinkage in valuation that the farmer has been forced to accept recently.

From 1914 to 1918 New York State ranked twelfth in respect to the total valuation of crops. In 1919 it was the fourteenth State, but in 1920 it held fifth place. From 1914 to 1918 Pennsylvania ranked fifth and in 1920 dropped to ninth place. For the same period Illinois was first in respect to all crops and in 1919 dropped to third place. Minnesota was ninth during this period and dropped to seventeenth place in 1920 in respect to all crops. The number of tractor companies and the sizes of machines built in 1920 are stated in Table 4.

TABLE 4—NUMBER OF TRACTORS BUILT IN 1920

Horsepower	Number of Companies	Number of Machines
8 and less	6	7,678
9 to 15	8	3,366
16 to 18	17	107,782
19 to 22	17	39,964
23 to 26	24	18,073
27 to 32	33	19,861
33 to 39	10	1,410
40 to 59	15	3,684
60 and over	13	1,389
	Total	203,207

Of the total of 203,207 machines manufactured, only about 29,000 were estimated as having been sold for export, leaving 175,000 for domestic trade. The total value of all farm equipment produced during 1920 was $537,000,000 and over $500,000 of this amount represents horse-drawn cultivating tools. Only $66,000,000 of this was estimated as having been sold for foreign trade, leaving $471,000,000 for domestic trade.

Our export business in all lines of farm equipment declined during the war, but production was normal except in 1918 and our surplus that formerly went to Europe was accumulating in this Country. Also, with our enormous increase in production during 1919 and 1920, caused by the urgent appeal of the Government officials, it is only reasonable to assume that we would have felt the effects of over-production in the farm-equipment line even if the farmer's product had maintained its price level. If one consults the records, it will be found that whenever our imports increase and our exports decrease so that the imports exceed our exports in value, we feel the effect in all lines of business. Not until our surplus begins to move to foreign countries will business conditions improve to any marked degree.

FARM-IMPLEMENT FINANCE

Much has been said and written about convincing the country banker of the value of farm tractors. Perhaps the people who feel that the country banker has not been convinced do not consider the matter from the banker's standpoint. One of the great troubles throughout the entire Country today is that the banker has been oversold. The country banks are not in a position

to extend further accommodation to the farmer until he has liquidated some of his present debts.

The principal business of the average banker is to accumulate in the bank's vault as much money as possible. This money must be sold to the borrower at a profit. The money does not belong to the banker; it belongs to the depositors and the law compels the banker to safeguard the interests of the depositors to the best of his ability. His only means of making money is to sell his depositors' money to the best advantage. He must not only have good security but must know that the borrower has other resources. No banker wants to resort to foreclosure to realize on the security given for a loan. The banker knows from experience that it is perfectly safe to loan a farmer money to buy horses, cattle or seeds and, if he finds it necessary to resort to the sale of his securities for any reason, he can realize the amount of the loan. There has always been a stable market for livestock; hence, the banker takes little chance of losing his money.

On the other hand, a majority of the farmers who desire to buy a gasoline tractor on credit expect the banker to take the tractor only as security. The banker must judge whether the tractor will be a profitable investment for the farmer. If the banker does not think the tractor will prove to be a profitable investment for the farmer, he refuses to loan him the money. I believe that all good bankers are ready and willing to loan money to any farmer who is responsible and entitled to credit; that is one of the banker's means for making money. The country banker has been criticized too severely for not financing the farmer in his purchases of tractors.

Tractor Suitability

In a recent report on tractors sent out by one of the largest advertising mediums it is shown conclusively that the broad level prairies are the best field for tractors. This indicates that the one-purpose tractor has proved successful in the grain-growing sections or the prairie country devoted strictly to grain, but the company making the report questions whether the present type of tractor has proved successful and economical in that part of the country where row crops are grown to a large extent, or on the smaller farms. This advertising firm does not doubt that we are a long way from having convinced the farmers of the practicability of motorizing their farms; in other words, it feels that the farmers are not thoroughly convinced of the value of power farming and will not be so convinced until the tractor builder produces a machine capable of doing really all of the farm work that is performed at present by horsepower. Another company sent out inquiries and of the replies from 400 farmers in sections where the principal crops are corn, cotton and other row crop, about 90 per cent can be classified as follows:

(1) Not fitted to general farm operation
(2) Tractors should be strong enough to plow and light enough to cultivate
(3) Cannot afford to buy a tractor for plowing and keep horses to cultivate

A bulletin recently issued shows that in New York State 252 farmers who own tractors were able to reduce their horse equipment 22 per cent. During October and November 1920, representatives of the United States Department of Agriculture visited 286 tractor owners in Ohio, Indiana and Illinois. On the average the tractors were used for 30.8 full days of the year. While 85 per cent of the plowing, 75 per cent of the discing and 41 per cent of the grain-cutting was done with the tractor, the cultivating of corn is the operation that requires the greatest amount of horse-labor in the shortest time on the farm.

Tractor Distributors' Opinions

I have received letters from three of the largest distributors of tractors, who have had years of experience in this line and know whereof they speak. I will quote them for further evidence of what is necessary to improve the tractor business. In a letter dated July 1921, one of them said that the company had not sold the number of tractors that it should have sold this year. A special agent of one of the large tractor-producing companies stated that the motor cultivator supplies the missing link in territory where row crops are produced, and that this would allow his company to sell tractors to farmers who formerly had refused to purchase them because they did not replace horses for the cultivation of the crops. This agent said also that in his opinion a large tractor is necessary on the large farm but that it is debatable whether such a tractor is profitable without the cultivator. The distributing company feels that with the convertible machine any farmer who tills 160 acres will find it a profitable investment because it can be converted from a tractor to a cultivator and will do practically all of the work on a farm of this size. An instance was given of a young man who, while a motor cultivator was being demonstrated, drove it about six rounds and did nearly three times as much work as his father and brother did together with their horse-drawn cultivators in the same time.

Another company stated in June 1921, that it was so firmly convinced that farm tractors are not adapted economically to the corn belt that it intended to discontinue their sale. The view was expressed that there is very little question that a tractor will replace very few horses and men on the average-sized farm, of say 160 to 200 acres, unless some means is arranged for taking care of the cultivation of the corn. Further, that the corn farmer must keep enough horses and men to cultivate his corn and that under these circumstances he has practically all the power he requires except for belt purposes; that it is therefore plain that the average farm tractor in the corn belt is fundamentally wrong in that it is not built along lines that cause it to function economically; and that it has been developed as far as it can be developed unless some method of handling the corn cultivation is incorporated into its mechanism, although there is no question that the present type of farm tractor is suitable for use in the wheat fields in the Northwest and in Western Canada.

In June 1921 the third tractor-distributing company wrote that it had done too much toward selling the farmer on the word "tractor", rather than selling him on a basis of design and performance. This company also stated its belief that the all-purpose machine is the one farm-power agent that will stand out as a real factor in the solution of general farm-power problems, because it is theoretically, practically and economically suitable.

Use of Molybdenum Steel in the Automotive Industry

By JOHN D. CUTTER[1]

DETROIT SECTION PAPER *Illustrated with* CHART AND DRAWING

THE author discusses the advantages of straight chrome-molybdenum steel, because it has the widest field of usefulness, and carbon-molybdenum steel in sheets for pressed-steel parts. Reference is made to a bibliography of test results and similar data. The use of molybdenum steel is first considered in connection with the light-weight car. The adaptability of this steel to frame construction and its use for other parts also are commented upon, inclusive of manufacturing costs, and several tables that embody comparative data are presented.

Three specific divisions of advantages gained through use of this steel are stated, and quotations are made under each division from reports and statements of metallurgists and manufacturers in support of these claims. The author believes that the use of molybdenum as an alloying element for steel will have a favorable effect on the economic status of the automotive industry.

MANY types of molybdenum steel have been produced. Some of them contain nickel or vanadium in addition to chromium and molybdenum. These exhibit extremely high physical properties but, when commercial factors are taken into account, it is apparent that the straight chrome-molybdenum variety has the widest field of usefulness and it is this type of steel, together with carbon-molybdenum steel in sheets for pressed-steel parts, that will be considered. The subject divides itself naturally into a discussion of the opportunities molybdenum steel offers for lighter construction and one relating to manufacturing costs.

Chrome-molybdenum steels show progressively higher physical properties as the molybdenum content is increased up to about 1 per cent. It is claimed that any particular steel in this series will possess, when properly heat-treated, somewhat higher characteristics than other types of alloy steel that are in the same class from a commercial standpoint; or, if steels were sold on the basis of physical properties, the chrome-molybdenum series would offer the greatest values. Tables of test results and many similar data have been published as indicated by the accompanying bibliography,[2] and complete information can be obtained from most producers of alloy steel.

[1] M.S.A.E.—Vice-president and metallurgist, Climax Molybdenum Co., New York City.

[2] Almo Steels, Crucible Steel Co. of America.
Molybdenum Commercial Steels, Climax Molybdenum Co.
Molybdenum as an Alloying Element in Structural Steels by Dr. G. W. Sargent. See *Transactions of the American Society for Testing Materials*, vol. 20, p. 5.
Molybdenum Steels by Dr. J. A. Mathews. See *Mining and Metallurgy*, February, 1921, p. 39.
A Suggested Method for Determining the Comparative Efficiency of Various Combinations of Alloys in Steel by J. D. Cutter. See *Transactions of American Society for Steel Treating*, vol. 1, p. 188.
Molybdenum Steels by Charles McKnight, Jr. See *Transactions of American Society for Steel Treating*, vol. 1, p. 288.
Molybdenum Steel and Its Application by M. H. Schmid. See *Transactions of American Society for Steel Treating*, vol 1, p. 500.
Physical Properties of Materials, Bureau of Standards Circular No. 101.
Molybdenum Frames Mean More Mileage by R. F. Dyer. See *Automobile Topics*, Jan. 22, 1921, p. 1143.

Fig. 1 illustrates the approximate relations of several standard alloy-steels to the chrome-molybdenum series. If it is true that molybdenum steels offer somewhat greater strength, all other things being equal, there should be opportunities for designers to reduce sections and save weight. It is recognized that in many members of a motor car extreme rigidity is required and that in such cases sections cannot be cut down by the employment of stronger material. It seems that there is a possibility, however, of allowing flexibility in some parts that ordinarily are made rigid. The frame is a case in point. It is usual to rely upon the frame to impart to the body the rigidity necessary for maintaining the proper alignment of doors and the like; but it is possible to incorporate stiffening members in the body itself and by suitable attachment of the body to the frame to allow great flexibility in the frame. This should add to the riding qualities of the car.

Fig. 2 illustrates the two methods. Certain cars have been constructed for years in the principle shown in the lower portion of this illustration. Flexible frames can be made of heat-treated alloy-steel and much lighter than the rigid frames. The question has been raised whether the weight that is saved in the frame does not have to be added to the body to give it rigidity. This has not been found to be the case. The body is not called upon to carry so heavy a load and the distance between supports is much shorter. For trucks, the light-weight flexible-frame should be extremely advantageous, as there is apparently no reason for rigidity in most cases.

ADAPTABILITY TO FRAME CONSTRUCTION

Molybdenum sheet steel, both with and without any chromium content, has proved especially adapted to the construction of frames. It can be rolled easily into plates or sheets free from laminations and having clean and smooth surfaces, can be formed without difficulty and, when heat-treated, affords high elastic limits. Reductions in weight can be effected up to 70 per cent of the carbon-steel rigid frame. Table 1 is a comparison of frame steels.

Heat-treated alloy steel frames will have a much

TABLE 1—COMPARISON OF FRAME STEELS

Type of Steel	Condition	Elastic Limit,[a] lb. per sq. in.	Possible Saving in Weight, per cent
Carbon	Untreated	40,500	0
Carbon	Treated	65,400	38
Straight Molybdenum	Treated	90,000	55
Chrome-Molybdenum (Mo 0.30 to 0.50)	Treated	120,000	67
Chrome-Molybdenum (Mo 0.80 to 1.00)	Treated	157,000	70

[a] The minimum elongation in 2 in. corresponding to the above figures for the elastic limit is 16 per cent. The dimensions of the test-piece are ¼ x ⅝ in.

greater longevity and resistance to fatigue, as the Stanton tests of Table 2, which is included through the courtesy of John Miller, metallurgist of the Pierce-Arrow Motor Car Co., Buffalo, indicate. This test approximates service conditions better than any other laboratory life-test of which I know.

TABLE 2—STANTON TESTS OF HEAT-TREATED ALLOY-STEEL FRAMES

Type of Steel*	Condition	Number of Impacts Before Fracture
Carbon	Untreated	67 (bent)
Carbon	Treated	3,376
Chrome-Nickel	Treated	11,418
Chrome-Molybdenum	Treated	13,071

*Specimens ½ in. wide and 5/32 in. thick; not rotated, supported on edge. Distance between supports, 4½ in. V-notch in center of bottom edge, 0.05 in. deep. Radius at point of notch, 0.02 in. Load applied at center of upper edge, 5½ lb. Weight dropped a distance of 1 in., 100 times per min.

Use for Other Pressed-Steel Parts

The performance of molybdenum sheet steel when used in frames has led to an investigation of its value as applied to other pressed-steel parts such as rims, disc wheels, hubs, rear-axle housings and the like. It is perhaps too early to make a positive statement as to the degree of success that will attend efforts to save weight in such members. The feasibility of heat-treatment has not been proved in all cases, and there may be mechanical limitations that will affect the reduction that would be possible from the purely theoretical standpoint of the strength of materials. The evidence to date, however, leads to the belief that important developments in this field are at hand. It should be noted that the parts mentioned are classed as unsprung weight and whatever saving is accomplished is double important for that reason.

The type of steel that has been most widely used in this connection is an ordinary deep-drawing stock to which about ¼ per cent of molybdenum has been added. Such a steel possesses extreme ductility in the rolled state and considerable strength when heat-treated, as will be seen by referring to Table 3. The test-piece was 1½ in. wide and 9 in. long.

TABLE 3—DUCTILITY AND STRENGTH; ¼ PER CENT MOLYBDENUM CONTENT

Thickness of Sheet, in.	Condition	Elastic Limit, lb. per sq. in.	Elongation in 2 In., per cent
5/32	As rolled	45,640	44.5
5/32	Quenched in water from 1600 deg. fahr. Drawn to 900 deg. fahr.	120,470	7.5

It has been said often that the total amount of alloy steel in the average car is not more than one-fifth of the total weight and that, for this reason, the employment of a steel of slightly greater strength could not affect the total weight by a very wide margin. However, molybdenum steel has without doubt broadened the sphere of usefulness of alloy steels greatly, thus multiplying the opportunities for lighter construction.

Molybdenum Steel and Manufacturing Costs

Molybdenum steel offers the greatest economy in the cost of material for given physical properties in the finished piece. Aside from this first cost there are those of forging, heat-treating and machining. So much has been published on the performance of molybdenum steels in these three basic operations, that only the briefest outline of the characteristics that have been noted will be offered here, together with supporting quotations from technical papers or written reports at various plants.

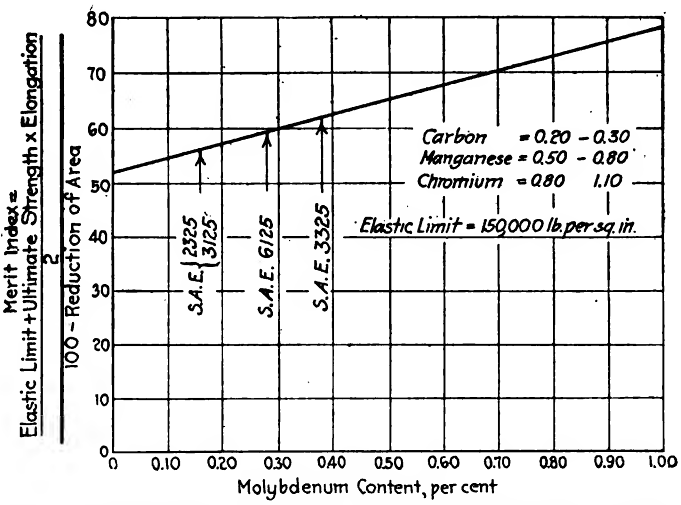


Fig. 1—Approximate Relations of Several Standard Alloy-Steels to the Chrome-Molybdenum Series

In forging, molybdenum steel offers a wide range of permissible temperatures, flows readily in the dies and throws the scale easily. The last quality is most pronounced in comparison with nickel-bearing steels and is a large factor in eliminating rejections.

A forging inspector states,

> It is apparent that chrome-molybdenum steel has a wider forging-range than chrome-nickel steel. We had one of the oldest and best hammer men in the shop on this job and he was highly pleased with the way that this steel worked. A new set of dies was used and the axle was filled out perfectly at all points, which is very unusual with chrome-nickel steel under the same conditions. There was no scrap from the 100 axles forged.

The research department of a large steel company reports,

> It is noticeable that the nickel-steel scale adhered very strongly to the bar and was very difficult to remove; and that the nickel-chrome steel showed the same quality to a less extent. But the scale on the chrome-molybdenum steel came off readily. The effect that this adhesion of scale has on the surface condition of finished steel during the working process is to increase the prev-

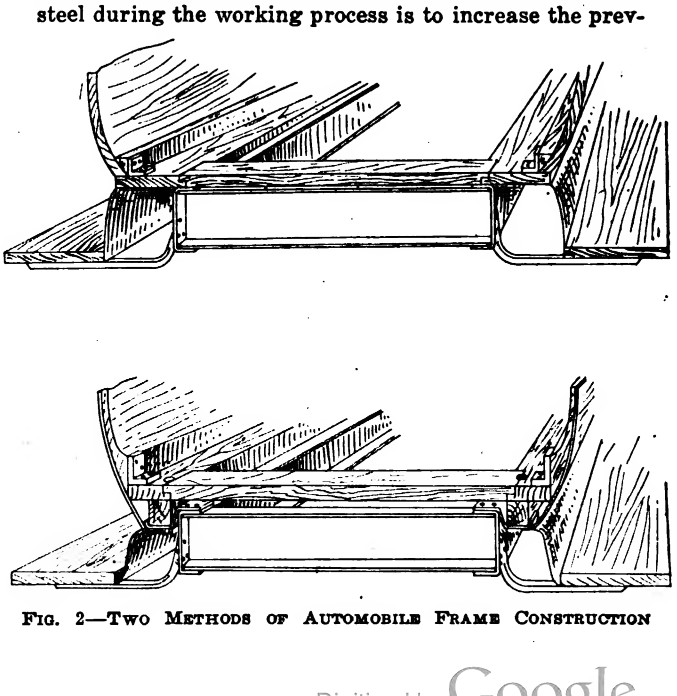


Fig. 2—Two Methods of Automobile Frame Construction

alence of pits and other surface roughnesses on account of having the scale rolled in.

Parts made of chrome-molybdenum steel, the analysis of which is controlled properly, can be quenched in water without fear of cracking. The range of temperature allowable in heat-treating is wide, which is a tremendous advantage in quantity production.

An automobile metallurgist says,

> Chrome and nickel steels have to be held within a very narrow heating-range before quenching and in drawing, to bring out the necessary physical properties to the best advantage. This has necessitated an elaborate temperature control, constant watchfulness and a very thorough inspection of all forgings passing out of the heat-treatment department. In the heat-treating of the experimental lots of forgings made from chrome-molybdenum steel, we quenched at temperatures varying from 1525 to 1600 deg. fahr. Our drawing temperatures varied from 1025 to 1150 deg. fahr. Despite this, all the forgings passed our physical requirements and no trouble was experienced with cracking.

The marked machinability of the steel, especially in the heat-treated state, is the quality that will have the greatest bearing on the decreased cost of production.

Dr. John A. Mathews, in a paper on Molybdenum Steels,[5] that was presented at the 1921 annual meeting of the American Institute of Mining and Metallurgical Engineers, says

> Molybdenum steels seem to machine more readily than other steels at a given Brinell hardness. This would mean, of course, that parts that must be heat-treated and machined afterward could be utilized in a state showing higher physical properties than have been obtainable customarily.

The automobile metallurgist previously quoted on the wide temperature-range possible for quenching and drawing says also,

> On the lathe operation our average production of nickel-steel steering-knuckles, with a Brinell hardness range of 253 to 283 and without regrinding the tools, has been 30. We were able to put through 100 chrome-molybdenum steering-knuckles with a higher Brinell hardness of 311 to 321 without regrinding, an increase of over 300 per cent.

Charles McKnight, Jr., works manager of the Carbon Steel Co., states,[6]

> In a laboratory test the machining qualities of chrome-molybdenum and nickel-chrome steel were obtained by heat-treating a specimen of each in exactly the same manner and at the same time. The physical properties of both were similar, with a slightly higher Brinell hardness on the chrome-molybdenum steel. These specimens were placed in a lathe and while the feed, shape of tool and depth of cut were kept constant, the speed was increased until one or the other turned to a blue color. This occurred first with the chrome-nickel steel and, when it did occur, no discoloration was apparent on the piece of chrome-molybdenum steel.

The following extract is taken from a report prepared by the time-study department of a well-known automobile plant:

> Operation No. 70 is to center both ends. The standard time per piece is 0.30 min. and it is the same on nickel steel. Centering tools will last approximately 25 per cent longer on this material than on nickel steel, according to our check. Operation No. 90 is to drill one hole ¾ in. in diameter, and 1 7/16 in. deep. The standard time per piece is 0.72 min. and it is 0.79 min. on nickel steel. The Baker drilling machine runs at a speed of 250 r.p.m., with a 0.013-in. feed; and at 250 r.p.m. with a 0.012-in. feed on nickel steel. A two-flute Detroit twist drill is used. On the test, 50 pieces were drilled on one grinding of the drill, which was still in good condition. On 3½-per cent nickel-steel the operator has to grind the drills every 10 or 12 pieces; also, there is a breakage of from one to three drills per day's run.

There is another important way in which molybdenum steels may have an effect on manufacturing costs. It is necessary to employ in automobile construction steels of a wide range of physical properties; however, standardization not only in production methods but in materials is the basis on which economical quantity-production exists. The fewer the kinds of material necessary, the greater the efficiency in purchasing and inspection will be. Molybdenum steel offers the possibility of a single basic type, in a few grades differing chiefly as to carbon content, covering all of the numerous combinations of properties required from the extremely hard ball-bearings through the various tempered, toughened or case-hardened articles to the ductility required in deep-drawing stock for pressed steel parts. Further, the analysis range of the several grades may often be contiguous. The benefits and economies accruing to both steel consumer and producer from such a procedure are obvious. The former can employ relatively narrower specification limits, while to the producer the chance of loss from "off-heats" is minimized.

The attempt has been made in this paper to show how the use of molybdenum as the principal alloying element in our steels might be an important factor in the ability of builders to produce lighter and more economical cars which, in turn, should have a favorable effect on the economic status of the industry. It has been stated also that this steel made economies in manufacture possible. It would not be proper to dismiss this subject without a few words as to the available supply of this metal. The huge deposits of molybdenum-bearing ores located in the United States constitute one of the most important and unique natural resources of this Country. The steel industry is assured of an adequate supply to meet any conceivable demand for an indefinite period. This is the only steel-alloying element that is so found within our borders; all of the others must be largely imported. Molybdenum alone can render us independent of foreign sources of supply for the metals necessary to the production of alloy steels.

THE DISCUSSION

A MEMBER:—Do you ever advise the use of molybdenum steel in the non-heat-treated condition for pressed-steel parts?

JOHN D. CUTTER:—The molybdenum steel that has been used in frames and in other pressed-steel parts exhibits a somewhat higher elastic limit in the rolled condition than the ordinary soft steel; an advantage can be gained but it is not nearly so important a one as when heat-treatment is employed.

A MEMBER:—Is the advantage as high as 10 or 15 per cent, or higher?

MR. CUTTER:—I think it is perhaps somewhat higher than that; about 20 per cent might be gained, with a 20-per cent reduction in weight.

A MEMBER:—What of the increased cost of heat-treatment and of straightening after heat-treatment?

[5] See *Mining and Metallurgy*, February, 1921, p. 39.

[6] See *Transactions of American Society for Steel Treating*, vol. 1, p. 500.

MR. CUTTER:—Some frame manufacturers have figured that the cost of the frame made of heat-treated alloy-steel is no greater than that of the soft-steel frame not heat-treated. In other words, the reduction in weight effected offsets the increased cost of the material and the cost of heat-treatment.

A MEMBER:—Does that apply to reduced sections?

MR. CUTTER:—Yes.

A MEMBER:—How does that affect the stiffness when the sections are reduced?

MR. CUTTER:—The stiffness is reduced when the sections are lightened.

A MEMBER:—Then it is not advisable to reduce the sections.

MR. CUTTER:—If stiffness is required, it cannot be done. For passenger cars, unless a change in body design similar to that illustrated in my paper is effected and the frame is not required to be rigid, there is no advantage in the heat-treated alloy-steel frame except that it overcomes the possibility of permanent set and has a higher factor of safety.

A MEMBER:—With the lighter section of steel a frame is produced that is flexible. Will this not allow greater wear on the spring-shackles and bearings?

MR. CUTTER:—I can conceive of that, yes. There have been several cars and trucks that have employed flexible frames for years and there has been no trouble from that source.

A MEMBER:—Is the finish any better than with carbon, chrome-vanadium or chrome-nickel steels?

MR. CUTTER:—I think no pits are eliminated as compared with straight carbon-steel; the finish has been reported to be much superior to that of nickel-bearing steels and of chrome-nickel steels also.

A MEMBER:—Is molybdenum steel rust-proof?

MR. CUTTER:—There is a patent on a very soft low-carbon steel that contains a small amount of molybdenum and is supposed to be rust-proof, but I have never proved that myself.

S. P. HESS:—Is this type of steel suitable for leaf springs?

MR. CUTTER:—It is a very good spring steel. The Fifth Avenue Coach Co., of New York City, had something like 60 such springs on its omnibuses and has been keeping an accurate record, taking them all off, measuring each set periodically and comparing them with the other alloy-steel springs that they use. Their report is very favorable. Only three springs have been broken to date, which is a lower percentage than they have ever attained before. It may be 10 years before they will present a full report.

MR. HESS:—What is the elastic limit in comparison with that of chrome-vanadium steel?

MR. CUTTER:—It is approximately the same; generally, it is about 180,000 lb. per sq. in. for most springs.

MR. HESS:—What is the comparison as regards length of life?

MR. CUTTER:—I think the bus test which I mentioned is the best one that I can quote, as indicating the length of life. My opinion is that fatigue is more dependent on the homogeneity of the steel than on any given analysis. No matter what their composition, I believe that if steels were subjected to identical physical stresses in a static test and were identically homogeneous, there would be very little difference in the length of life.

MR. HESS:—What should be the percentage of molybdenum content of spring steels?

MR. CUTTER:—The molybdendum content in the steels actually used has varied between 0.3 and 0.5 per cent but it can run from nothing to as high as 1 per cent.

MR. HESS:—I understand that there is a slight percentage of copper in molybdenum steels. Does that have any influence on molybdenum steels in a heat-treated state?

MR. CUTTER:—It may have an influence. Most of the ores of molybdenum are very free from copper. Our own molybdenum ore is almost entirely free from any copper-content.

MR. HESS:—Is not the ore found usually in the copper districts? Possibly the trace of copper is due to that fact.

MR. CUTTER:—It is found in the Rocky Mountains and so is copper, but there is not very much copper near the deposits. There is merely a trace discoverable occasionally and most concentrates that are on the market today are very free from copper. There is no danger of copper being introduced into molybdenum steels as a class or of its having an injurious effect on the steel.

MR. HESS:—What is the approximate limit of heat-treatment on molybdenum steel for springs, with reference to the quenching operation?

MR. CUTTER:—When the carbon content is as high as it is in spring steel, I believe that the range is nowhere near as wide as it is in the lower-carbon forging steel. Springs should be heat-treated accurately.

MR. HESS:—I ask that question because we know that chrome-vanadium steel has a wide range.

MR. CUTTER:—I believe chrome-molybdenum steel has an equal range, but that fatigue or impact tests are apt to narrow that range in both steels.

H. G. PEEBLES:—The Bureau of Mines states that the penalty is high for copper content in the ores. Has any headway been made in the last 2 years regarding the separation of copper from the molybdenum in the ores of the Southwest? I understand that the Mexican mines have been closed on account of the copper content.[7]

MR. CUTTER:—We had some concentrates offered us from that district not long ago and rejected them on account of the copper content. There are some deposits that have a large copper content but ours have not. The Mexican molybdenum mines are negligible.

C. W. JINNETTE:—Is molybdenum steel used in crankshafts, camshafts and piston-pins?

MR. CUTTER:—Yes, it has been eminently approved in a number of places. Some shops have found that they can eliminate straightening operations by the use of molybdenum steel in crankshafts because the distortion is not so great; the machinability is good. The piston-pins and camshafts would be of carbonizing steel, and it appears that the elimination of chromium in the carbonizing steel would make even a better steel than the chrome-molybdenum case-hardening steel. There is a very pronounced effect of the molybdenum in steel for carbonizing purposes. The carbon penetrates very much more rapidly than it does with a steel containing nickel. In some cases the time has been reduced materially in the carbonizing process. The core can be made extremely tough and the case hard and strong.

MR. JINNETTE:—Is there any trouble due to cracking?

MR. CUTTER:—No; I have never heard of any such trouble.

MR. JINNETTE:—How do the tooling or grinding costs compare?

MR. CUTTER:—I have no such data. I presume that would be a function of the hardness.

MR. JINNETTE:—We find in grinding that we have had

[7] See Bureau of Mines Circular No. 3, p. 37.

slightly more trouble and that we require softer wheels. The metal takes a beautiful finish.

MR. CUTTER:—But do you not find that the wheels must be changed oftener and that you cannot use the wheels for so long a time?

MR. JINNETTE:—Yes, it requires wheels from 1 to 3 grades softer and in some instances a little coarser than the ordinary wheel used on camshafts and crankshafts made of drop-forged low-carbon steel. The grades of wheel ordinarily used are too hard on both the finishing and roughing operations.

A MEMBER:—Have you rolled any steel as thin as 0.035 in. and, if so, have you had any difficulty in rolling it?

MR. CUTTER:—No, the thinnest stock has been 0.064 in.

A MEMBER:—In rolling a sheet like that without lamination, have you had any difficulty in keeping it flat?

MR. CUTTER:—No such difficulty has been reported by anyone who has done that work. I am having some steel cold-rolled to 0.01 in.

R. W. WILSON:—Have you made any recommendation regarding molybdenum steel for axle shafts?

MR. CUTTER:—The specification would depend upon the design and the stress to which the axle shaft would be subjected. The type of molybdenum steel that has been most widely used and recommended for axle shafts is of 0.40 per cent carbon, with 0.80 to 1.10 per cent of chromium and 0.25 to 0.40 per cent of molybdenum.

MR. WILSON:—What elastic limit does it have in the heat-treated condition?

MR. CUTTER:—That depends upon the drawing temperature. Elastic limits can be obtained for axle shafts as high as 175,000 lb. per sq. in., and perhaps higher than that.

MR. WILSON:—What elongation would that permit?

MR. CUTTER:—About 12 per cent.

MR. WILSON:—How does that steel compare with the S.A.E. No. 3140 steel in price?

MR. CUTTER:—The type of steel I mentioned would be somewhat more expensive than the No. 3140 steel. It would cost about the same as 3½-per cent nickel or S.A.E. No. 2340 steel.

W. C. PETERSON:—In connection with gears and particularly transmission gears that are oil-hardened, what are the abrasive qualities of molybdenum steel?

MR. CUTTER:—Very few oil-hardened gears have been made of chrome-molybdenum steel. Transmission gears have been made of a chrome-nickel-molybdenum steel that, so far as I know, have exhibited the best qualities in regard to resistance to abrasion. They are used in the Wills-St. Claire car. The steel showed an elastic limit of about 300,000 lb. per sq. in.

MR. PETERSON:—Is it true that the elongation curve runs in a straight line over a considerable part of the drawing temperature-range? I refer to the chrome-molybdenum series of 0.40 per cent molybdenum, 1 per cent chromium and about 0.40 to 0.45 per cent carbon. Does not the elongation curve remain a straight line over a distance say from about 500 to 800 deg.? If that be true, does the impact change from a comparatively low value at 500 deg. to a considerably higher value at 800 deg.?

MR. CUTTER:—It is considerably higher, undoubtedly, at 800 than at 500 deg.

MR. PETERSON:—But the elongation does not change; that is different from other steels.

MR. CUTTER:—I think the range you state is somewhat high. I think the elongation curve is rather flat at low drawing-temperatures; that is, if one goes back from 200 to 600 deg., but it surely begins to rise before 600 deg.

MR. PETERSON:—The curve remains a straight line from 400 to 750 deg. and the impact value at 400 deg. was low. It was out of order as compared to other steels. I had time only to find out that the impact value was gradually becoming greater as we came near 750 deg.

MR. CUTTER:—The tests that I have from steel companies on that type of steel do not show that pronounced flatness of the elongation curve at such high drawing-temperatures as you mention. I have no impact-test result on that type of steel at those low drawing-temperatures.

A MEMBER:—Has molybdenum any advantages over tungsten, as an alloy in cutting tools? The experiments carried out by the Navy Department some 5 or 6 years ago indicated that it was inferior to tungsten for roughing work and, in a small proportion, it seemed to help out the cobalt-chrome combination, but the matter was dropped after a very short time and, so far as I know, no work has been done in that direction for a number of years past. As I understand it, molybdenum acts as a substitute either for tungsten in a cutting tool or for cobalt in a service member, so to speak. Just as a rough approximation, how would you compare molybdenum to tungsten?

MR. CUTTER:—I would not compare it because, in high-speed or cutting steels where molybdenum is used as a substitute for tungsten, a content of 4 to 8 per cent is required and, when added to steel in those relatively high percentages, molybdenum has been found not practical. Cutting steels made with molybdenum as the principal element have been extremely efficient and given very good results on cutting tests, but it has never been possible to duplicate those tests; it has never been possible to make a number of pieces of steel that would show a high average result. I think the reason is that molybdenum has a tendency to volatilize near the surface of the steel when added in those high percentages. In fact, a yellow smoke can be noticed coming off the steel when it is heated for forging or rolling. Perhaps there is a chance for a molybdenum high-speed steel for tools that are to be ground considerably, but for a standard steel to be used for all purposes I think that it is not practical at all. So far as I know, no molybdenum high-speed steels are being made in this Country. In combination with cobalt, there have been molybdenum high-speed steels for which great things were claimed, but they have been withdrawn also.

A MEMBER:—I presume that the molybdenum chip is rather fragile; that it is torn off in a brittle flake rather than pulled out like a fiber.

MR. CUTTER:—We know that is the case with screw stock. H. T. Chandler, of C. H. Wills & Co., has an intesting explanation of the superior machinability of molybdenum steel in the heat-treated state as compared with other alloys. He attributes it to the greater reduction of area because, as a tool passes through the steel, the steel that has the property of necking down the most, as exhibited in the tensile test, will not have so much material affected on either side of the tool, and therefore it machines more easily.

A MEMBER:—In what way would molybdenum be superior to tungsten in the ordinary service members of the automobile? So long as tungsten sells at about one-half the price of molybdenum, it certainly would be a competitor as regards cost.

(*Concluded on page* 347)

The Summer Meeting

As this issue of The Journal goes to press, the number of reservations for the Summer Meeting has reached 421. Consideration of the fact that the meeting will not convene until June 20 convinces one that a large attendance is assured, and also serves to remind the tardy that the choicest rooms are being disposed of rapidly. For the convenience of those who have not yet forwarded their applications for rooms, a blank is printed on page 69 of the advertising section of this issue of The Journal. Mail this to the offices of the Society with your check or money order at once. The hotel is not permitted to accept applications direct.

The Technical Sessions

Progress has been made by the Meetings Committee in the selection of papers to be read at the Summer Meeting and the program is practically completed at this early date. Six sessions have been decided upon and will be known as the

(1) Research Session
(2) Fuel and Engine Session
(3) Passenger-Car Session
(4) Aeronautic Session
(5) Motorbus Session
(6) Service Engineering Session

A report from the Research Department of the Society will be the nucleus of the Research Session. This report will treat principally the motor-fuel-volatility and highway-research projects in which the Society has been participating. Fuel tests are being conducted as outlined by the Research Department, the Bureau of Standards and the Bureau of Mines, and the full support of the National Automobile Chamber of Commerce and the American Petroleum Institute is expected.

Several papers will be presented in the Fuel and Engine Session. Thomas Midgley Jr., whose contributions are always received with interest, will submit some data on the characteristics of blended fuels. Two papers will be contributed on the pumping of oil in engine cylinders, a current problem demanding special study. One of these will be presented by an engine designer, A. A. Bull, and the other by a lubrication engineer, G. A. Round. A paper on the present status of the hot-spot method of handling fuels of low volatility will complete the group of papers in this session. This will be presented by F. C. Mock.

Complete plans for the Passenger-Car Session are not ready for announcement, although two papers have been definitely settled. Our national meetings would not seem complete without at least one technical paper from the automotive laboratory of the Bureau of Standards. This summer its paper will relate to a device perfected by the Bureau that records graphically the fuel consumption of a passenger car while it is being operated under ordinary driving conditions. An analysis of records kept over a long period reveal some rather unusual facts

Looking West Along the South Facade of the Greenbrier Toward the Mountains in the Vicinity of White Sulphur Springs

RAILROAD ACCOMMODATIONS TO WHITE SULPHUR SPRINGS, W. VA., FOR SUMMER MEETING JUNE 20-24, 1922

		TIME SCHEDULE				RAILROAD FARES	
City	Railroad	Leave	Arrive Cincinnati	S. A. E. Special Leaves Cincinnati	Arrive at White Sulphur Springs	Fare-and-Half Round-Trip	Tourist Round-Trip
Cincinnati	Chesap'ke & Ohio			9:45 p.m.	8:55 a.m.	$19.08	$20.62
Detroit	Big Four	11:45 p.m.	8:55 p.m.	9:45 p.m.	8:55 a.m.	28.08	31.97
Toledo	Big Four	1:35 p.m.	8:55 p.m.	9:45 p.m.	8:55 a.m.	24.98	28.22
Chicago	Big Four	1:00 p.m.	9:00 p.m.	9:45 p.m.	8:55 a.m.	34.47	38.70
Indianapolis	Big Four	6:15 p.m.	9:00 p.m.	9:45 p.m.	8:55 a.m.	25.01	27.75
Cleveland	Big Four	3:00 p.m.	9:35 p.m.	9:45 p.m.	8:55 a.m.	29.01	31.11
Dayton	Big Four	7:57 p.m.	9:35 p.m.	9:45 p.m.	8:55 a.m.	22.02	22.73
City	Railroad	Leave	Arrive Washington	Leave Washington	Arrive at White Sulphur Springs	Fare-and-Half Round-Trip	Tourist Round-Trip
Boston	New Haven	9:00 a.m.	8:45 p.m.	10:15 p.m.	7:05 a.m.	$37.76	$47.24
Providence	New Haven	10:06 a.m.	8:45 p.m.	10:15 p.m.	7:05 a.m.	36.74	45.88
New Haven	New Haven	12:54 p.m.	8:45 p.m.	10:15 p.m.	7:05 a.m.	29.28	35.94
New York City	Pennsylvania	3:40 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	25.37	30.92
Manhattan Transf.	Pennsylvania	3:58 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	25.37	30.92
West Philadelphia	Pennsylvania	5:56 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	20.51	24.89
Baltimore	Pennsylvania	8:30 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	15.32	18.68
Buffalo	Pennsylvania	9:10 a.m.	8:50 p.m.	10:15 p.m.	7:05 a.m.	34.25	39.56
Washington	Chesap'ke & Ohio			10:15 p.m.	7:05 a.m.	13.16	17.28

which command the attention of all who covet an increased number of miles per gallon. W. S. James will present this paper. The wider adoption abroad of overhead-valve passenger-car engines may indicate the tendency of future engine design in this Country. At any rate, a paper on the subject is pertinent at this time and P. M. Heldt will present it in this Session.

The Aeronautic Session will include papers on several phases of aircraft progress. Only two of these can be definitely announced at the present time, these being offered by Capt. G. E. A. Hallett, of the Air Service engineering staff at McCook Field, and Prof. E. P. Warner. Capt. Hallett will describe the methods followed by the Air Service in the design, experimental construction and testing of its new engine types. The success of the McCook Field organization in the rapid development of radically new engines may mean that some of its methods will apply advantageously in the work of industrial engineering organizations. The paper by Professor Warner will deal with a method of estimating airplane performance. It is based on theory but practical data taken from actual performance-tests will be presented. The Meetings Committee also hopes to secure papers on the progress in metal construction and the application of duralumin.

The extremely rapid growth of motorbus transportation has naturally brought this branch of the industry into greater prominence and interest in this phase of automotive engineering is at a high pitch. Two papers have been scheduled for the special Motorbus Session. G. A. Green, who has been identified with the motorbus ever since its introduction in New York City and elsewhere, will treat of the important factors that influence bus design and construction. R. E. Plimpton will submit data showing the unusual growth of bus transportation and compare the many types of bus chassis now produced, indicating the particular service to which each is suited.

Improvement of repair and maintenance service, decreasing repair costs and the engineer's part in advancing these steps will hold the attention of the members at the Service Engineering Session. Two major papers will be read and a number of shorter ones will be discussed in the form of a symposium. J. B. Bray will offer the constructive criticisms of the factory service-manager. His paper will not deal so much with design as with practices of the average engineering department that are detrimental to the execution of an ideal service policy. The engineer's views on the same subject will be set forth in the other paper by one of our members well qualified to present them.

Many of the papers will be circulated in preprint form or included in the June JOURNAL, so that all may have ample time to prepare thorough discussions of them for presentation at the various sessions.

RAILROAD TRANSPORTATION

The Society has been exceedingly fortunate in securing reduced-fare concessions from practically all of the railroads for the Summer Meeting. The plan will follow that used at West Baden last year and the privileges are limited to members of the Society and *dependent* members of their families. Certificates will be mailed to all members about June 10 that entitle the purchaser to a fare-and-half rate for a round-trip ticket. The certificate must be presented when your ticket is purchased and requires validation at White Sulphur Springs before boarding the return train. All tickets purchased under this plan can be used on the S.A.E. Special trains announced herein. The secretaries of the Sections will be provided with an extra supply of certificates for those who may need them.

Two S.A.E. Special trains have been arranged for to transport the Eastern and Western contingents to the Summer Meeting. The use of these trains by the members has much to recommend it; there will be no aggravating changes to make; you will travel with your fellow members of the Society and your friends in the industry. A railroad representative will be in charge of each train to see that everything runs smoothly. Consult your Section Secretary or write the Society offices to make reservations on either train. The Midwest Section will have special Pullmans out of Chicago. Detroit and Cleveland will also provide special Pullmans. Metropolitan, New England, Pennsylvania and Washington Sections will all have special cars on the Eastern train.

The tourist fares are shown in the table for the benefit of those who have non-member guests coming to the meeting. The guests may avail themselves of the lower tourist-rate. The Society is held responsible under the

Interstate Commerce laws for any violation of the agreement limiting the fare-and-half return privilege to members and dependent members of their families. *No tickets will be validated at White Sulphur Springs for non-member guests.*

Sports and Entertainment

The next issue of the *Meetings Bulletin* will include the detailed sports program of the Meeting and an entry blank for those who plan to engage in one or more of the numerous events. The companies in the industry have contributed liberally to the prize-purchase fund and the Sports Committee can assure the members appropriate and excellent rewards for the victorious. Tennis, golf, swimming, track and field events will be arranged for the men. Croquet, golf, quoits and cards will test the skill of the ladies. There will be inter-Sectional baseball games, relay races and tug-of-war. Every imaginable branch of sport is provided for at White Sulphur Springs. The tennis courts are first class; the golf course is one of the finest in the South; the natatorium is modern and attractive. You are certain to enjoy your visit to the 1922 Summer Meeting.

The Entertainment Committee is centering its efforts on the many diversions that are being planned for the ladies who attend the White Sulphur Springs Meeting. Several novel departures are to be featured; and the evening dances and movies of past meetings will be outdone. The ladies will have the option of no idle moments at White Sulphur Springs, rest assured of that.

Viewed from all angles, it is safe to predict that the 1922 Summer Meeting will be unusually attractive and well attended. Spend your vacation with your friends in the Society at beautiful White Sulphur Springs.

Most important of all, send your reservation in at once. The blank is on page 69 of the advertising section.

MOLYBDENUM STEEL IN THE AUTOMOTIVE INDUSTRY

(*Concluded from page* 344)

MR. CUTTER:—Such tests as I have witnessed do not show the combination of strength and ductility that is obtained with molybdenum. I think that the tungsten steel is rather apt to be lacking in ductility.

A MEMBER:—So far as I know, no one has ever seriously advocated tungsten steel for automobile parts. That is very likely due to the past high price of tungsten and the demand for that element in cutting tools.

MR. PETERSON:—To what members in an automobile, aside from the valves, do you refer to?

A MEMBER:—I presume that it would be practicable to use tungsten steel in any member in which increased strength would be desirable. Considering the general properties of tungsten as compared with molybdenum, it seems that it would be reasonable to experiment with it in that direction.

MR. PETERSON:—I believe that considerable experimenting has been done along those lines. So far as I have learned, metallurgists are satisfied that tungsten can function only in the cutting tools because of its ability to give the red-hardness property, but other than that it has no value.

MR. CUTTER:—I believe that even if tungsten should show some degree of usefulness for structural steel, the supply of it would be too limited to make its use possible commercially.

P. T. LARGE:—The ductility of molybdenum steel has commended itself to some of the automobile wheel-rim manufacturers.

MR. CUTTER:—I think that developments in that connection will be interesting. There is undoubtedly a demand for a reduction in unsprung weight, especially in the peripheral weight of the wheel, which is the rim. I believe a great advance is possible, that heat-treated rims are feasible and will be produced very shortly. The section ought to be reduced at least one-half. Such rims have been made for installation on racing cars with very good results.

GEORGE L. BIXBY:—Provided the body were properly supported or stiffened, would you consider it feasible to take 70 per cent of the actual weight out of the frame?

MR. CUTTER:—From the standpoint of strength of materials, yes. There may be limitations that would affect the possible reduction of weight; such as the riveted joints in the frame. As the section is reduced, one must take care of the attachments for step-hangers and the like. The method has been to use a larger number of smaller rivets. We do not know yet how far that can be carried. The 70-per cent reduction in weight was based on a steel of 1/16-in. gage, that has been used in a very light frame that I believe is being run on an experimental car now. So far as I know, it has been maintained successfully. I think one cannot use steel very much thinner than 1/16 in.

A MEMBER:—One example of extreme flexibility in automobile frames is the case of the Orient buckboard. I think it had no springs; the road shock was absorbed entirely by the body of the vehicle itself.

RECENT INTERNAL-COMBUSTION ENGINE RESEARCH

(*Concluded from page* 336)

using the heavy crude fuel that you have been using in a Diesel engine.

Mr. McDewell asked an interesting question as to how far dissociation plays a significant part. I have no actual figures available at the moment, but certainly dissociation plays a very important part in determining the maximum flame-temperature; but that is all. Neither Mr. Tizard nor I have contended that dissociation plays any very serious part in the efficiency of an engine. Probably, and I think it is quite arguable, if one suppresses the dissociation altogether, the efficiency would be lower because of the higher temperatures involved and the consequent direct heat-loss. It does, however, play a part in that it puts the value of high compression on a better footing than it would appear. I think this is the main point, that it gives one a higher efficiency at high compression-ratios than one would otherwise expect to obtain.

Mr. McDewell also inquired whether the good luck I had with the stratified-charge engine applied also to the supercharging engine. Insofar as the stratification of the charge was concerned, I had plenty of trouble and very little luck with this engine in other directions, chiefly due to excessive detonation and, until I eventually discovered that air-scavenging was the cause of this, I could make very little progress.

Paint Protection for Wood

By Cornelius T. Myers[1] *Illustrated with* Charts

About two years ago in carrying on some research work on wood wheels I had occasion to make inquiry among paint manufacturers as to the value of various kinds of paint and primer for the protection of wood against moisture. This inquiry brought out so many differences and variations in opinion as to paint materials and mixture-proportions that a more extensive inquiry among paint men was started. This inquiry revealed that

(1) There was little or no technical information to be gained from the paint industry on the relative protective values of different coatings for wood
(2) The paint industry did not recognize the moisture-proofing of wood as a problem, but was concentrating so far as the more reputable manufacturers were concerned on producing paints that would last as long as possible on the surface to which they were applied. In other words, such improvements as have been made have contributed to the life of the coating rather than the life and usefulness of the article that received the coat

As the demand upon our forests depends to a very considerable extent upon the life of forest products, and as the life of these products in many cases depends to a very great extent upon the protection against moisture they receive, the intimate knowledge of protective coatings is a factor of great importance in our lumber conservation program; to say nothing of the possible saving in our $300,000,000 annual paint bill. Wood in its natural green condition has a very limited use as a structural material. Its tiny fibers are cellular in form and contain a large amount of moisture, commonly known as sap, the sap being water containing very small percentages of tannins, sugars, gums and coloring matters. To give the physical qualities that make it fit for use in buildings, furniture, truck bodies, wheels, etc., it is necessary to remove most of the moisture.

Moisture in Wood

Wood is said to be oven-dry when continued oven-drying causes no further loss of weight. In their green state the woods used structurally have a moisture-content of from 60 to 120 per cent of their oven-dry weight, and weigh roughly from 60 to 120 per cent more than when they are in an oven-dry state. In other words, from 35 to 55 per cent of the weight of a green log is water. In the green log this water exists in two conditions:

(1) Minute particles of water in each tiny wood cell cavity, known as "free water"
(2) The moisture absorbed by the fibrous material that forms the walls of the cells, known as "hygroscopic moisture"

Felled wood exposed to average atmospheric conditions gradually dries, the air taking up its moisture. First the cell cavities slowly give up their moisture. This evaporation goes on until the cell cavities are emptied of the minute bodies of "free water" they contain. All that remains is the moisture actually absorbed by the fibers of the cell walls, which are still saturated with the "hygroscopic moisture." Wood in this state is said

[1] M.S.A.E. Consulting Engineer, Rahway, N. J.

TABLE 1—APPROXIMATE PERCENTAGE OF INCREASE IN STRENGTH OVER GREEN[2]

	Dried to 14-Per Cent Moisture	Dried to 8-Per Cent Moisture
Bending Strength, Modulus of Rupture	40 to 60	80 to 100
Compression Parallel to the Grain	80 to 90	100 to 150
Compression Perpendicular to the Grain	65 to 75	
Stiffness, Modulus of Elasticity	20 to 30	25 to 35[a]
Hardness	30 to 35	40 to 50[a]
Shearing Strength, Parallel to the Grain	40 to 50	60 to 70[a]

[a] Estimated.
[2] Compiled from data given in Timber, Its Strength, Seasoning and Grading by H. S. Betts.

to be at its "fiber-saturation point." Up to this time the wood does not change appreciably in size or in physical characteristics except as to weight, which of course decreases considerably, as it will now contain but from 25 to 30 per cent of moisture instead of from 60 to 120 per cent.

Further drying of the wood is necessary to increase its strength and hardness, increase its durability, enable it to take and hold paint and in general to improve its condition for the purpose intended. As this drying progresses beyond the fiber-saturation point the cell walls give up the moisture they have absorbed and in doing so shrink and harden. Under natural conditions this drying process will continue until the amount of moisture in the wood bears a definite relation to the average humidity condition in the particular locality (See Fig. 1). In the Eastern and North Central States, for instance, the moisture-content of wood will become stabilized somewhere in the neighborhood of 14 per cent for what is known as thoroughly air-dried stock. In the arid Southwestern States it will contain a still lower percentage, while in the former war zone of France the wood will normally contain considerably more than

TABLE 2—SHRINKAGE AND MOISTURE CONTENT OF HARDWOOD[3]

	Specific Gravity of Dry Wood	Shrinkage[7] from Green to Oven-Dry in Terms of Green, per cent Radial	Tangential	Moisture in Green Wood in Terms of Dry Wood, per cent
Ash, White[4]	0.57	4.8	7.0	39
Birch, Yellow[4]	0.55	7.4	8.9	68
Elm, Cork	0.57	4.8	8.1	53
Hickory[5]	0.64	7.2	10.9	60
Maple[6]	0.51	4.2	8.5	63
Oak, Red[6]	0.56	3.9	8.3	83
Oak, White[6]	0.60	5.3	8.8	66
Average	0.57	5.4	8.6	62

[3] See Kiln Drying of Lumber by H. D. Tieman, p. 129.
[4] Average of 2 species.
[5] Average of 9 species.
[6] Average of 3 species.
[7] The average shrinkage along the grain or up and down as the tree grows is only about ⅛ per cent.

14 per cent of moisture. Of course, the moisture content of wood will vary to a certain extent with seasonal changes of atmospheric humidity, the rate at which the wood will follow these changes depending upon the degree of protection by paint and upon the area of the exposed surface. Thus unpainted wood that is exposed to rain and snow will absorb considerably more than 14 per cent depending upon the dimensions of the piece and the extent of the exposure.

Data secured from the Forest Product's Laboratory of the United States Department of Agriculture show us that

(1) Many woods should be dried to about 8-per cent moisture-content to give the best results as to strength, durabiltiy, hardness and finish (see Table 1)
(2) It is also true that if after being dried, and shrinking in the process, wood reabsorbs moisture, it will swell again according to the amount absorbed
(3) The shrinking and swelling along the grain, perpendicular to the annular rings and tangential to the annular rings all differ, and very materially, for a given change in the moisture-content (see Table 2)

From the above mentioned tables it will be seen that it is desirable to have the wood thoroughly dried, and that steps should be taken to keep it so. But, although it is easy to reduce the moisture to 8 per cent in dry kilns, it is difficult to maintain the wood at this point, because of unsuitable protective coatings or processes, and of the lack of knowledge as to the relative ability of various coatings for really stabilizing the moisture content within a small range.

Protectiveness of Paint

While we know that several coats of good paint will give adequate protection for floors, truck bodies, furniture, wheels or other wooden articles, we by no means know what paints give the best protection or what paints will give fairly satisfactory protection for the least money. The test fences, where many different paints were exposed to the same atmospheric conditions, have given some data on the durability of paints, but very few data on the durability of the painted article or its dimensional stability. *In durability and dimensional stabilization we are greatly interested;* in the first for very obvious reasons, in the second because wooden structures, furniture and the like are durable and serviceable and can be made more simply if their various component parts do not expand and contract with changing weather conditions. The cost of drying could be reduced in many cases, if when dried to a certain point the moisture-content could be stabilized. Wood, on account of its very valuable characteristics, could be used in places where metal now seems necessary. A dozen or more prominent companies in the paint industry have been cooperating very commendably in this research work, realizing that the dimensional stabilization of wood by moisture-proofing is a proper function of paint and of world-wide importance. There is, however, much difference of opinion among these manufacturers as to what materials should be used and how they should be mixed and applied. During the war the Forest Products Laboratory investigated the moisture-proofing effects of linseed oil and various paints, varnishes and leaf-metal coatings as applied to airplane propellers and other airplane parts made of wood, but this work has not been broadened because of lack of funds.

To get some comparative data on the paints and primers now on the market, I drew up the following schedule and tests were made on small pieces, measuring

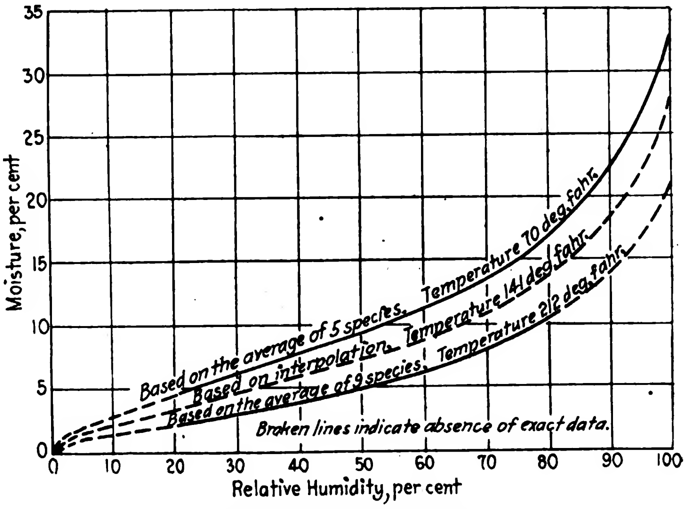


Fig. 1—Relation between the Amount of Moisture Absorbed by Wood and the Average Relative Humidity

1 x 1 x 4-in., of hickory, oak, birch and maple by several well-known paint firms.

(1) Dry slowly and completely until pieces cease to lose weight
(2) Determine "oven-dry" weight
(3) Allow reabsorption to 8 per cent
(4) First coating to be applied at 8-per cent moisture-content

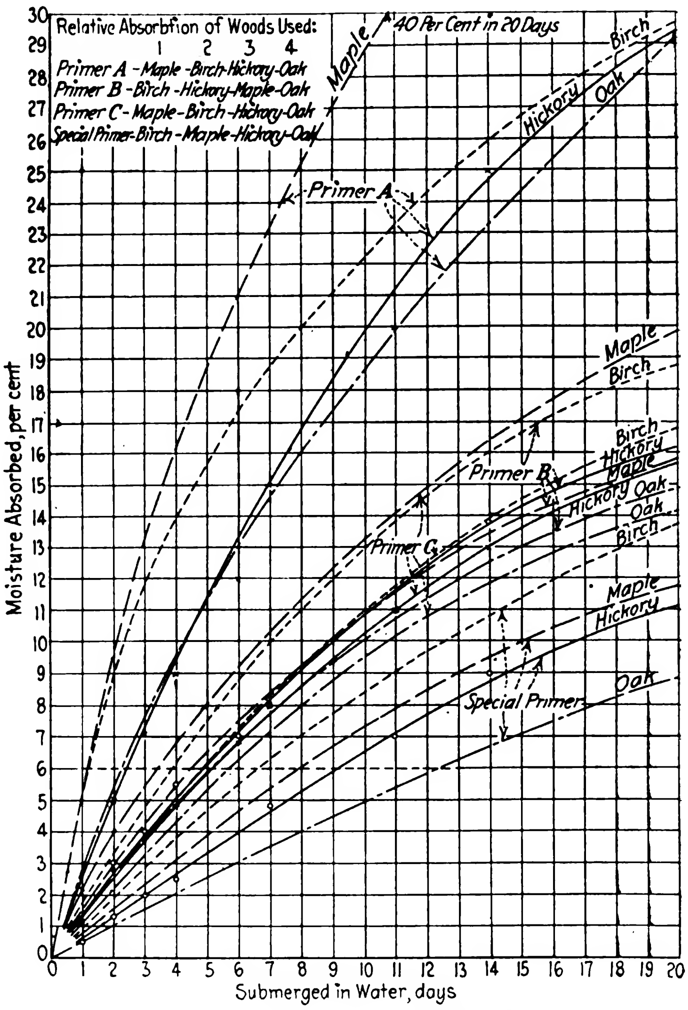


Fig. 2—Curves Showing How the Effectiveness of Different Primers as Moisture-Proofing Agents Varied for Different Woods

(5) Second coating to be applied at 8-per cent moisture-content after a lapse of 24 hr.
(6) Third coating to be applied at 8-per cent moisture-content after a lapse of 24 hr.
(7) Allow the three coatings to dry for a week under 70 to 80-deg. fahr. temperature and 40-per cent relative humidity, under which condition the moisture-content of the wood should remain at 8 per cent even if the wood had no protective coating
(8) Label and weigh for base weight at 8-per cent moisture-content with protective coating
(9) Submerge in water at 70 deg. fahr.
(10) Weigh every 24 hr. for first week and every 48 hr. thereafter and determine percentage of increase in moisture
Note: Bear in mind, of course, that whatever is used in the way of coatings must serve as a suitable foundation for subsequent coats of paint and varnish

In general, the results of the tests showed that paints of the ordinary brands and formulas are not very effective as moisture-proofing agents, even when three coats are applied. One paint company after testing its standard brands did a little experimenting and without much difficulty was able to produce a special primer that was several times as effective. The curves in Fig. 2 show emphatically the variations in effectiveness of the paints used. Averaging the results for hickory, oak, maple and birch, it took about six times as long for these test-pieces to absorb an extra 6 per cent of moisture when coated with the "special" as when coated with the standard "A". There is every reason to believe that much better results can be secured and with less than three coats. Preliminary tests with a casein solution indicate that it has water-proofing qualities which for some classes of protection may be very valuable. The same thing is true of some of the pyroxalin compounds. Varnishes are in general more effective than paints, but in the protection of wheels their application is not suitable for primary coats.

Need for Research

What has been said so far shows the need for research work on this subject. Cabinet and furniture makers are vitally interested in a coating that will prevent wood from "working," shrinking and swelling, due to atmospheric changes in winter and summer. Interior woodwork could be greatly simplified if the dimensions of each particular piece of wood would remain the same or vary but a very small amount. Flooring, decking, paneling and the like would be greatly benefited if it did not "work." Many wooden structures would be simpler and more permanent if so protected, and with thoroughly dried timber they would either have a greater factor of safety or could be built with less lumber. Many other advantages will develop as thought is given to this subject, the dimensional stabilization of wood by rendering it moisture-proof to some substantial degree.

It is well known that shingles and weatherboards fastened with old-fashioned wrought-iron nails stay tight much longer than those in which the modern steel nail is used. The reason for this is that the steel nail rusts and is flaked off by the movement, or "working", of the piece through which it is driven. A nail tightly driven is practically sealed against external moisture by its head and the paint around it but if moisture reaches the nail by the capillary action of the wood fibers, the nail will rust in spite of end-sealing. Then, too, the moisture and capillarity of the wood cause the "working" that rubs off the layer of rust and exposes the nail to continuous corrosion. The working also abrades the wood and leaves the familiar large, rust-stained hole around an attenuated nail. The same conditions apply to the bolts and other steel fastenings in farm machinery, wagons, motor-truck bodies and a long list of other articles. It is of vast importance in wood construction, therefore, that we have paints to protect the wood from absorbing moisture. Ordinary paint does not do this effectively except when a large number of coats are applied and so far as I have been able to find out, there has been little or no attempt to produce a paint that will do it.

In the realm of house painting there seems to be a great possibility for economies, either by the use of cheaper paints that will give the necessary protection, or by the use of paints that will last longer. I am not familiar enough with this subject to do other than to refer to Dr. A. H. Sabin's letter to the *Engineering News-Record*[8] in which he states that even the Pennsylvania Railroad is not always able to protect itself in the matter of paints, and asks what chance the ordinary citizen has to check up on the paint he should use to protect the house that very possibly represents his life's savings. Paint literature of a technical nature is of no assistance to the average man and is entirely inadequate to explain the whys and wherefores of much present practice. Great differences of opinion and some vague reasoning appear. Many contentions seem to be based on a desire to use certain materials or formulas rather than on comparative service data of a reliable sort. Such men as Dr. Sabin of the National Lead Co., and Dr. Holly of Acme White Lead & Color Works, make frank acknowledgment of the shortcomings of paint technology and totally disavow any detail information concerning the effect of paints in moisture-proofing the cell structure of various kinds of wood. The Engineering Foundation has approved the idea of research in this connection and appointed a committee to report ways and means of furthering it. This is a most substantial endorsement. The American Institute of Architects also will lend its support, and the matter has been favorably considered by the Council of the Society of Automotive Engineers.

It would seem that an intimate knowledge of wood cell structure is essential to any investigation of this subject. The Forest Products Laboratory is by all odds our most authoritative source of information on woods and their structure. The director and his staff have been interviewed and fully agree that this research would be productive of important results, some of which could be expected in the course of 8 to 12 months; also that it can be handled there if funds in a very modest amount, between $10,000 and $20,000 per year, were made available for, say, from 5 to 10 years. The Bureau of Standards has a paint division and has funds to work on the paint end of the research. Doubtless a cooperative arrangement could be made between these two of the most capable and helpful arms of our governmental service. Doubtless, too, the technical heads in the paint and varnish trade would place at the disposal of the Bureau of Standards and the Forest Products Laboratory their great fund of knowledge of paints and oils. Many of these men are already working on this problem as has been set forth above; but they are handicapped by a lack of intimate knowledge of the various kinds of woods, and they are very much limited in the time they can give and the range of materials they can test.

[8] See *Engineering News-Record*, Aug. 18, 1921, p. 291.

Photographic Recording of Engine Data

By Augustus Trowbridge[1]

Annual Meeting Paper *Illustrated with* Photographs and Diagrams

BELIEVING that it is one of the functions of the purely scientific man to direct engineering attention to practical possibilities that will be of use in solving important problems, the author outlines the history of the photographic recording apparatus he describes later in detail and comments upon its general features that are of advantage in engineering practice, with illustrations, inclusive of the use that is made of the string galvanometer.

The subject of indicators for high-speed engines is discussed in general terms introductory to a full and detailed description of how this automatic photographic recording apparatus can be used to overcome difficulties that pertain to ordinary indicator-diagrams taken on the internal-combustion engine by former methods. A further use of this apparatus is in anti-knock research and its recent usage for this purpose is described and illustrated.

UNTIL a few years ago I shared what I believe to be the general feeling among technical scientific men that photographic methods of recording experimental data such as pressure-volume variations in an engine cylinder, vibrations of shafting and motion or timing of valves, could not be rendered sufficiently simple, cleancut and foolproof to be reliable in the hands of the ordinary intelligent mechanic, but nearly two years' experience in France during the war convinced me that photographic recording is the quickest, cheapest, most cleancut and foolproof method that exists. I was in charge of the sound-ranging service in the American Army, the object of which was to locate the positions of the enemy large-caliber guns by recording the time of the arrival of their sound-waves at known positions near our own trenches. An accuracy of about 50 ft. in 5 miles was required and a delay of more than 4 or 5 min. in recording, calculating and reporting, to our own artillery headquarters was considered excessive. The work was carried on by the ordinary enlisted man who had been given but a few weeks' special training; and it was always conducted under rather unfavorable conditions, in the cellars of ruined houses or in crowded dugouts. I believe that the photographic methods that withstood this test continuously for months without a breakdown are suitable for use under almost any conditions.

Success was due chiefly to the fact that all operations were made strictly automatic. The camera was designed to use a cheap sensitized paper that was fed from a roll past a stationary lens through which the exposure was made. The paper was automatically developed and fixed before it left the camera, so that there was no chance whatever of confusion of records when a great many were being taken in rapid succession, since the operator could inspect and mark with a pencil each record as it issued from the camera.

Since the war, I have adopted this apparatus for the purposes of the physicist when I have needed to make use of photographic methods and, as will be developed somewhat in detail, I think it is adapted to the purposes of those who are interested in securing good internal-combustion-engine performance and in locating the sources of undesirable noises that it is desirable to eliminate.

General Features

In the present apparatus a simple mechanism allows the record to be taken at one speed and developed at a slower speed so as to give sharp contrast. Exposure speeds up to about 4 ft. per sec., with an ordinary automobile electric-light bulb as a source of light, can be used. The automatically developed records show a contrast that is entirely satisfactory. A series of fine lines reaching clear across the paper is photographed at the same time as the record. These lines are spaced 0.01 sec. apart, even if the speed of the paper should vary slightly, and serve as time-lines to time accurately an event shown on the record; for example, the opening of an exhaust-valve.

An automatic recording camera can be used to trace the motion of any moving part of a mechanism and, owing to the high speed at which a record can be taken, it is possible to study variations that occur in time intervals as short as 0.001 sec. It is more convenient to transmit electrically to the camera the motion that actually takes place in the mechanism than to attempt to set up the camera itself close to the mechanism. I have found that a special form of simple string galvanometer is very convenient and meets satisfactorily the necessary condition that its moving part shall move synchronously with the motion of the mechanism. The moving part of the galvanometer is practically weightless, as it is a short piece of wire 0.004 in. in diameter, and its motion is damped strongly by the magnetic field in which it is placed. When a current is sent through this wire, it moves in the magnetic field and a shadow of this motion is photographed by the automatic camera. In practice, almost any slight motion can be converted into a flow of electricity, so that the applications of photographic recording to the study of vibrations in running machinery are very numerous.

If it is desired to study the pressure-changes within the cylinder of an engine that is operating, a capsule with a stiff diaphragm can be screwed into a pet-cock opening and the motion of the diaphragm recorded as the motion of the string of the galvanometer. The records of the pressure-changes made at every stage of the cycle of the running engine are very instructive, as shown in the charts presented later of some of the many records I have made of engines running under various conditions of load, speed, mixture, spark-setting and temperature.

On any one record, it is possible to secure a great many successive explosions and so to compare them and draw conclusions as to the constancy of performance under supposedly constant conditions. The timing of the valves or the spark can be determined *dynamically* with an accuracy of about 0.0005 sec. This means about 6 deg. of crankshaft travel in the case of an engine that is running at 2000 r.p.m. Thus, the lag between the static and the

[1] Professor of physics, Princeton University, Princeton, N. J.

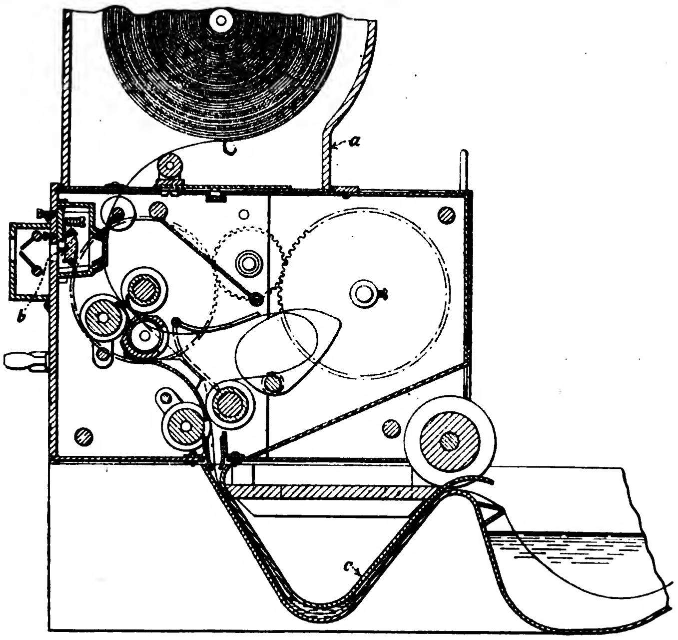


Fig. 1—Apparatus for Recording Engine Data Photographically

dynamic timing can be determined at various engine speeds.

Detailed Description

The essential feature of a foolproof photographic recorder is that it requires but slight attention from the operator, so that he will make as few mistakes as possible. The portion of the apparatus shown in detail in Fig. 1 is a camera that employs sensitized paper in 200-ft. rolls that are stored in the holder at *a*. This paper is run downward vertically before a lens at *b*. The film is then carried through the developer in the housing at *c* and run out into the fixing bath that lies outside of the camera. After starting to develop a film, one need not fear the effect of light, since the fixing can be carried on in a room lighted sufficiently so that one can see to read easily. The entire apparatus can be operated in daylight. The film is developed in the dark and fixed in daylight; so, the operator can reject films that are not interesting, or he can mark with a pencil those that he wishes to keep.

It is necessary to have some kind of a time-scale on the same paper film. In the device that I have used the beam of light with which the photography is done is cut by the spokes of a wheel that spins accurately, being governed in its spinning by the motion of a tuning fork that is caused to vibrate by electrical means. All this apparatus takes care of itself automatically. The small spinning wheel has spokes that come into the path of the light and cast shadows on the film every 0.01 sec. These shadows are photographed across the film as it runs vertically past the lens and the interval between the photographs of these shadows on the film gives a time-scale of 0.01 sec. This may be as much as 0.50 in. from line to line, if necessary, and 0.50 in. in 0.01 sec. is a very high speed. The light needed can be furnished by an ordinary automobile bulb operated from a 6-volt circuit, such as can be bought at any garage. Fig. 2 shows the spoked wheel at *d* and the tuning fork that drives it, seen in the direction in which the light travels through the lens. Fig. 3 gives a diagrammatic sketch of the electrical connections.

The apparatus as described thus far will record on a rapidly moving strip of paper an accurate time-scale in hundredths of a second and the motion of any moving object or objects such as the shadow of a fine wire that is in motion. There remains to describe how such a fine wire can be made to move so that its motion will be the same as, or related to, the motion of a mechanism that is operating and which it is desired to investigate.

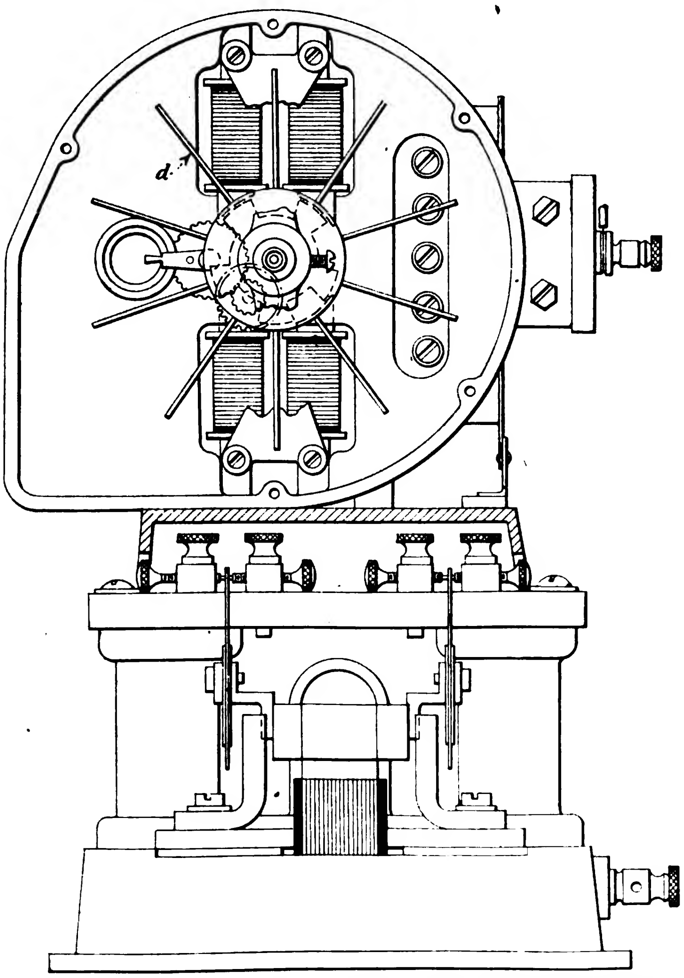


Fig. 2—Detail of the Spoked Wheel That Casts Shadows on the Film To Indicate the Time Intervals and the Tuning Fork That Drives It

The String Galvanometer

The device that I have been using is an old one that was discovered by Einthoven, a Dutch physicist, 20 or more years ago. It is known as the string galvanometer and is merely a small electromagnet furnished with current from the same battery that supplies the light, operates the tuning fork and turns the spoked wheel.

In Fig. 4, *N* represents the north pole and *S* the south pole. There is a small hole vertically down through the strongest part of the field. One or more fine tungsten wires, each about 0.0005 in. in diameter and 1 or 2 in. long, run down through this hole as indicated at *e* and *f*. Two lenses are located at *g* and *h*, through which the light from a small nitrogen-filled electric-light bulb passes and causes the fine tungsten wires to cast shadows. When a wire moves, its shadow moves on the photographic film and it is the motion of the shadow that one photographs along with the time-lines that are 0.01 sec. apart.

Fig. 5 shows the complete plan of the optical system. The light is at *i*. A spoke of the wheel, *j*, has come into a horizontal position. The lens at *k* forms a real image of *i*. The rays cross and go through the two lenses *l* and *m*, the light between them being an intense parallel beam. Two small tungsten wires are shown as dots at *n* and *o*,

because they appear only as in a plan view. Their shadows are thrown on the photographic film at *p*. If either wire moves, its shadow moves and one obtains a record of its motion on the photographic film. A blind to regulate the amount of light is shown at *q*, and a cylindrical lens at *r* reduces the images of the wires *n* and *o* to points and the image of *j* to a fine horizontal line.

Fig. 6 shows in elevation the holder of the fine tungsten wires *n* and *o*. Once the wires are mounted in the holder, one is not likely to break them; they are too thin

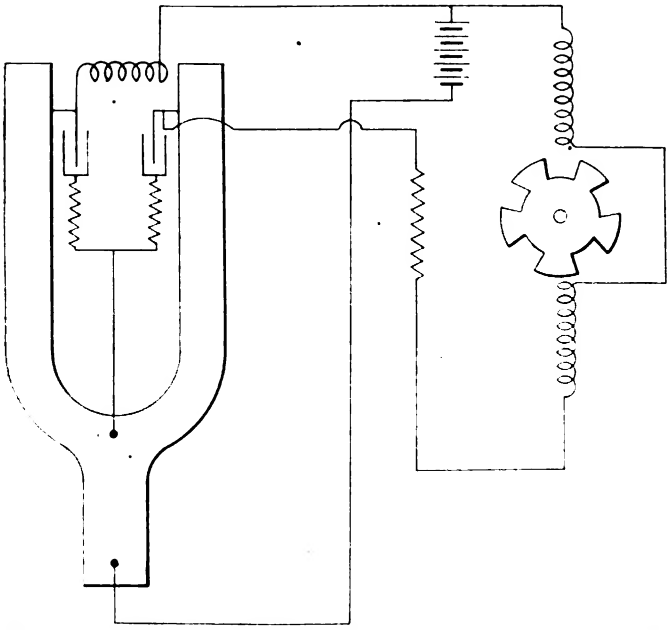


FIG. 3—DIAGRAMMATIC SKETCH OF THE ELECTRICAL CONNECTIONS

to break. If one blows upon them, they offer virtually no resistance. They have practically no weight and, on account of this lightness, they have no free period of vibration of their own and hence reproduce faithfully the motions impressed upon them. To use this device, by which one is able to photograph a tungsten wire 0.0005 in. in diameter that is moving rapidly, it is necessary to cause it to move. Since it is in a magnetic field, it can be caused to move across this magnetic field by sending an electrical current through it. It is merely a case of transforming the motion that one desires to make into a flow of current, sending that current through the

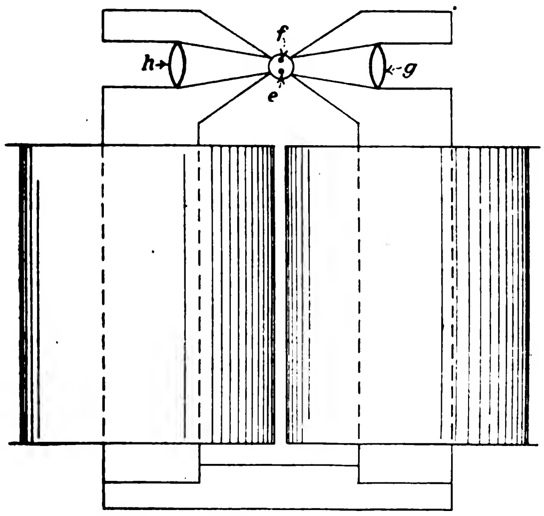


FIG. 4—DIAGRAMMATIC SKETCH OF THE STRING GALVANOMETER

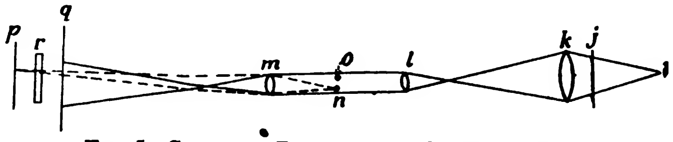


FIG. 5—COMPLETE PLAN OF THE OPTICAL SYSTEM

tungsten wire and photographing the motion of that wire's shadow on the sensitized paper of the camera. I have used this device for a great many purposes and I will now explain how it can be used for obtaining indicator-diagrams from an internal-combustion engine.

INDICATORS FOR HIGH-SPEED ENGINES

There are numerous good and sufficient reasons why the indicator has not played so important a part in the design and testing of the internal-combustion engine as it did in the case of the steam engine. The high speed at which the former is run makes it very difficult to construct an indicator the motion of which is characteristic of the pressure variations in the cylinder and not characteristic of the inertia and elastic properties of the indicator itself. In addition, the standard form of indicator-diagram, in which the pressure of the hot gas in the cylinder is shown as a function of the volume that the gas occupies at any instant, is most unsuitable in the case of the internal-combustion engine, for the diagram is crowded together at the in-center and out-center positions

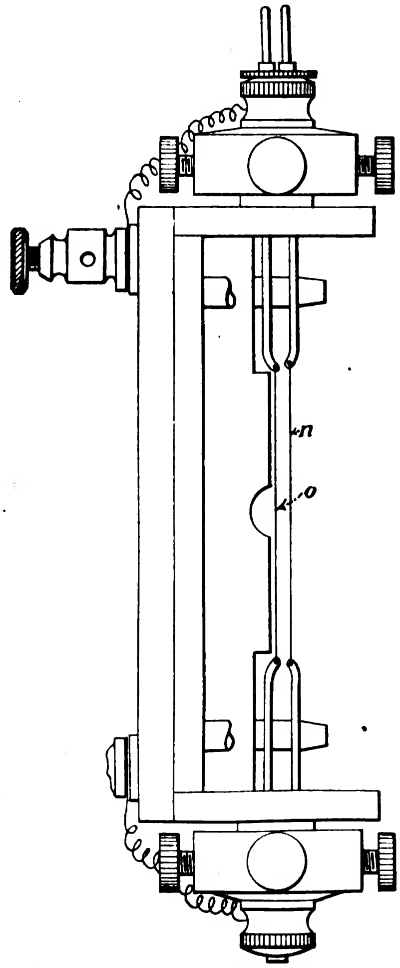


FIG. 6—ELEVATION OF THE HOLDER FOR TUNGSTEN WIRES

and these are just the positions near which the ignition, or spark, occurs and where the valves are opening. Thus, the very portion of the diagram where the most open

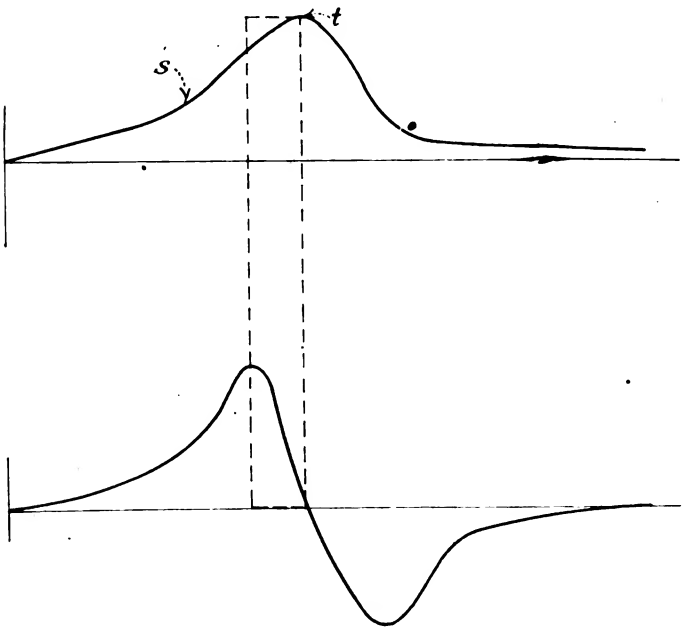


FIG. 7—A PRESSURE-TIME DIAGRAM (ABOVE) AND (BELOW) THE SAME DIAGRAM REPLOTTED IN TERMS OF THE RATE OF VARIATION OF THE PRESSURE

scale is desired is that at which the diagram practically stands still. Engineers acknowledge generally that a more unsatisfactory diagram than the old fashioned pressure-volume diagram would be difficult to devise, and indicators more suitable for work with internal-combustion engines have been designed to record the pressure as a function of the time, so as to provide a scale that is as open near the in-center and out-center positions as at the middle of the stroke. In the upper part of Fig. 7 a pressure-time diagram is shown in which the spark occurs at *s* and the maximum pressure at *t*. This is the type of diagram furnished by a pressure indicator of the type that is being used by Thomas Midgley, Jr.

I have found that a considerable further gain in accuracy is obtainable by changing the form of the indicator-diagram. If, instead of registering the pressure as a function of the time, the *variations of the pressure at each instant of the stroke are recorded,* wherever there is a change of slope on the pressure-time record there will be a nick on the record showing the pressure-variation as a function of the time or phase of the piston motion. In other words, my thought was to record the *rate of change of the pressure with the time,* as being a step farther in advance, in place of recording the pressure with the time or the pressure with the position of the piston. By plotting directly as vertical heights the *rate* at which the pressure is changed with the time instead of the pressure itself, a nick is produced in the curve.

It is naturally much easier to notice and time such a nick than to notice what may be but a slight change of slope on a pressure-time record, and such records are in consequence much easier to interpret with accuracy. After all, the chief use of an indicator is to assist one in noticing *changes* in the running conditions of an engine when *changes* in the fuel, spark-setting, speed and the like are made, and therefore an indicator that is designed to bring out *changes* is the most useful form practically.

It is easy to construct an indicator that will record the rate at which the pressure is varying instead of recording the pressure itself. An indicator in which a very stiff steel diaphragm is the moving part can be made so that the diaphragm moves in step with the pressure exerted upon it, and introduces no vibrations peculiar to itself. If a small bobbin of fine wire be mounted rigidly on the diaphragm so that in its motion it cuts a radial field of magnetic force, an electromotive force is induced that is in step with the *velocity* of the bobbin; that is, with the time-rate of variation of the pressure exerted on the diaphragm that supports the bobbin. The currents that are induced by the movements of the bobbin in that magnetic field are proportional to the velocity of the diaphragm and, as the velocity is proportional to the rate at which the pressure is varying with the time, one obtains an indication of the pressure-variation in the cylinder with the time that can be photographed. This results in a diagram that is particularly sensitive to pressure changes and well adapted to use in the timing of the valves and the spark. It is possible to design the parts just mentioned with such robustness that they will withstand rough treatment and yet be free of inertia and elastic effects that would introduce motions characteristic of the indicator. The motions are, as they should be, characteristic of the pressure-changes taking place in the cylinder.

I have plotted this diagram in terms of the rate of variation of pressure at the bottom of Fig. 7. It is a graph of the tangent to any point on the curve in the upper portion of Fig. 7. Maximum pressure that appears at *t* in the upper portion appears on the lower diagram as the point at which the rate of change of pressure is zero where it crosses the time axis. It is easy to time the arrival of maximum pressure on a (dp/dt) t diagram and it is not so easy to do this on a pressure-time diagram. All of the timing operations become very much more delicate if the indicator is recording the rate of pressure rather than the pressure itself.

Fig. 8 shows a typical curve produced by an indicator that records rates of variation of pressure with time. Compression begins at A_1; the point at which the compression has risen to nearly a maximum value and where the spark occurs is at B_1. The rate of rise of pressure becomes enormous at C_1 and the maximum pressure comes

FIG. 8—A TYPICAL INDICATOR-CARD PRODUCED BY AN INSTRUMENT THAT RECORDS THE RATE OF VARIATION OF THE PRESSURE WITH THE TIME

FIG. 9—DIAGRAMS OF A SERIES OF OBSERVATIONS IN WHICH THE SPARK-TIMING WAS VARIED

In the Upper Left Diagram the Spark Was Greatly Retarded and Was Gradually Advanced in the Diagrams in the Upper Right and Lower Left Corners until the Maximum Advance, Which Was Much Too Far, Was Attained in the Diagram in the Lower Right Corner

FIG. 11—AN INDICATOR RECORD OF THE ACTION OF THE FRONT END OF AN ENGINE CRANK-SHAFT AT SPEEDS (FROM TOP TO BOTTOM) OF 600, 425 AND 700 R.P.M.

FIG. 10—THE PHOTOGRAPHIC RECORDING APPARATUS AS SET UP TO INVESTIGATE THE SOURCES OF NOISE IN ENGINES THAT ARE RUNNING

at D_1 where the trace crosses the time axis. The maximum rate of fall of pressure comes at E_1 and the opening of the exhaust-valve occurs at F_1. This causes a sudden decrease of pressure that is shown between F_1 and G_1. The out-center position is shown at G_1. The lower portion of Fig 8 shows the positions of in-center and out-center of the piston.

The diagrams in Fig. 9 represent a series of observations beginning at the upper left-hand illustration, where the spark is very much retarded, and ending at the lower right-hand diagram with the spark much too far advanced. The record at the lower edges of all of these diagrams gives the time of in-center. Thus, in the first diagram, the spark occurred considerably after in-center and the pressure rise due to combustion was hardly more than the compression pressure. The fall in pressure when the exhaust-valve opens is very rapid, because burning was still going on due to the lateness of the spark.

The diagram in the upper right-hand corner shows the effect of advancing the spark. The pressure is rising closer to in-center and the amount of "dump-out" of pressure at the time the exhaust-valve opens is growing less. The spark is advanced still farther in the lower left-hand diagram and the rate of pressure-rise becomes greater. The dump-out of pressure at the opening of the valve is no more than that shown in the upper right-hand diagram, although the pressure has been higher. The beginning of vibrations in the gas can now be noticed. The rising portion of the curve after in-center was very smooth in the upper right-hand diagram, but in the lower left-hand diagram it is beginning to be broken into vibrations of about 500 to 1000 per sec. There is the beginning of a knock coming into the explosion. The spark in the lower right-hand diagram is set very much advanced, purposely, and the effect of the knock, which is enhanced, can be seen.

These diagrams are presented to give an idea of the

FIG. 12—A SIMILAR RECORD OF VALVE ACTION

In the Top Diagram the Rocker-Arms Were Held on the Tappets: in the Next Everything Was Adjusted Tightly; the Next Record Was Obtained with a Loose Adjustment between the Rocker-Arms and the Tappets and the Bottom Diagram Shows the Effect of Holding the Rocker-Arms Tightly on the Valve-Stems

kind of record that one can obtain. I have taken them at engine speeds as high as 2500 r.p.m. The scale is ample to afford a clear study of the effects of changes of mixture, spark, load, engine speed and other features of interest.

Anti-Knock Research

Thomas Midgley, Jr., has been using this particular indicator recently and Figs. 10 to 12 illustrate his use of it in studying the sources of noise in engines that are running. He has recorded two sets of data in this manner. In obtaining the data shown in one set, he was interested in studying the action of the valve and that around the camshaft. In the other set, the behavior of the crankshaft in regard to chasing and wobbling in its bearings was studied, with engines that he reports as having been thought to be in the pink of condition.

Fig. 10 shows his set-up of the entire apparatus. The recorder is shown on the table at the center of the illustration. One advantage of a self-contained recorder of this sort is that the apparatus can be shaken without shaking the parts relatively to each other; whereas, if a beam of light is thrown out from one support upon a screen that has a separate support, all of the records exhibit wiggles in the lines. In such a case one cannot be certain whether these wiggles are due to legitimate reasons or to the general vibration of the apparatus.

Fig. 11 is intended to show the effect of chasing motions of the crankshaft itself. The apparatus was arranged so that a wheel was carried on the end of the crankshaft. Fastened by springs to that wheel, exterior to it but concentric with it, was a heavy piece having a large amount of inertia. This was provided with brushes to carry off electrical currents and these were conveyed to the recorder.

The idea is that, since the crankshaft is turning around, if it were turning at a uniform speed it would carry this large inertia-piece with it at a uniform speed, and there would be no relative motion between the floating, heavy, inert piece and the crankshaft itself; but if the crankshaft is accelerating and retarding, there would be relative motion between it and the inertia-piece.

It was arranged so that, as the two moved with reference to each other, a small magnet was plunged into a tiny coil, having its contacts connected to the recording instrument; hence, any relative motion that occurred would be recorded as wiggles in the lines of the record. If one were dealing with a steam turbine, one would have a perfectly straight line down through the middle of the record, but if the power comes on in spurts as it does even in a multi-cylinder engine, there will be an acceleration of the crankshaft, it will again chase ahead of the floating piece, the floating piece will tend to catch up with it and there will be indications as shown in Fig. 11. For example, at the top of Fig. 11 is evident a very good sharp explosion from the engine followed by another good explosion, but there was evidently something extra that came in there, some extra wiggle that was not caused by the explosion, and neither one of the two explosions on the left is particularly sharp. They show extra vibration and an extra source of noise for some reason.

The top curve in Fig. 11 shows the engine when idling at 600 r.p.m. It was then put under full load and the engine speed fell to 425 r.p.m. It will be noted that the engine was missing fire, as shown in the middle curve but, in addition, under a heavy load, such sharp breaks do not appear as when under no load at all. The engine was then run idle at a higher speed, approximately 700 r.p.m. Once in a while there are sharp breaks and from time to time there are extra breaks. Evidently, there is a source of some vibration other than that due to the mere blow of the explosion each time. The engine is over-running. The amount of over-run and chatter can be measured with fair accuracy from the shape of the curve. It shows up best in the first wiggle to the left in the bottom curve.

The other test that Mr. Midgley made was on valves and rocker-arms. A small piece of soft iron, made adjustable, was carried on the rocker-arm that came into the field of a permanent horseshoe magnet. A few turns of wire around the magnet were connected with the recorder. Every time the rocker-arm moved in the field of the permanent magnet, a current was induced in the coil, this, in turn, setting the tungsten wire in the field of the galvanometer to moving and producing a wiggle on the record.

A number of tests are shown in Fig. 12. The rocker-arms were held tightly on the tappets. The top view represents the rise and fall, showing a very regular motion free from chatter. In the next view, with everything adjusted as tightly as possible, Mr. Midgley got a particularly small and sharp uniform motion of the parts; in the third view he had the adjustments rather loose, purposely. Comparing this last with that at the top, it will be noticed that the lost motion has begun to show up quantitatively. One can determine how much it is and how long it lasts and compare good adjustments such as those shown in the two upper views with bad adjustments such as those shown in the view directly beneath them.

The view at the bottom shows an attempt to hold down one end and not the other. The rocker-arms were held tightly on the valve-stems just as in the second view they were held tightly on the tappets. Again, when lost motion was taken up purposely, there was less chatter. The records in the two upper views and that at the bottom show a very good performance compared with that in next to the bottom view, but the record in the view directly above it is the best.

The records I have presented here do not include those from bad-acting valves or engines generally and so they do not show the worst kinds of trouble that one can get. They give an indication of what one can work toward.

THE DISCUSSION

J. H. Hunt:—What is the natural period of that vibrating element? What is its sensitivity in regard to current? I can use it in an entirely different way from the one Professor Trowbridge has outlined.

Prof. A. Trowbridge:—One can have any free period desired; it depends upon the tension. I have been using it so that it had no period at all. The damping is really of more importance than the question that Mr. Hunt raises. I had considerable trouble with that. The instrument that I designed for use in the Army was not properly damped; when I returned home I redesigned it so that I have a practical instrument. It is heavily damped.

In regard to its current sensitivity, I usually work with a deflection of about 10^{-4} amp. per mm. (0.03937 in.). The resistance of the tungsten wire itself is in the neighborhood of 15 or 20 ohms. The wire should be made as short as possible. Most people are wrong in that. The string should be made as short as possible because the damping depends upon its length. Damping is much

(*Concluded on page* 368)

Molecular Movements During Combustion in Closed Systems

By Thomas Midgley, Jr.[1]

Pennsylvania Section Paper *Illustrated with Photograph and Charts*

THE paper is an exposition of the theoretical analysis made by the author of the experimental work of Woodbury, Canby and Lewis, on the Nature of Flame Movement in a Closed Cylinder, the results of which were published in The Journal in March, 1921. No experimental evidence is presented by the author that has not been derived previously by other investigators.

The relation of pressure to flame travel is derived first, the relation of mass burned is considered and a displacement diagram constructed, described and analyzed. The break of the flame-front curve, called the "point of arrest," enters prominently into the discussion and computations; the pressure in the flame-front is studied; the reaction-velocities are calculated; and general comments are made.

The mathematical analysis is supplementary to the paper itself and includes the calculations for the relation of pressure to flame travel, pressure drop in the flame-front, and the actual and the theoretical reaction velocities.

THIS paper presents a method of analyzing the behavior of all portions of a gas as it undergoes combustion in a closed chamber, a photograph of the flame-travel and a pressure-time card being used as a basis for the analysis. It is shown how the movements of these gases are affected by the progress of the flame-front. The physical forces set up by combustion are disclosed and the actual reaction velocity of combustion is derived. The paper is purely analytical. No experimental evidence is presented that has not been derived previously by other investigators. The particular piece of experimental work that is used for the basis of this analysis is that carried out by Woodbury, Lewis and Canby, at the Eastern laboratory of E. I. du Pont de Nemours & Co., and presented in their paper on The Nature of Flame Movement in a Closed Cylinder,[2] at the 1921 Annual Meeting of the Society.

An outline of the procedure followed by Woodbury, Lewis and Canby in their work is that a bomb 1 ft. long and 4 in. in diameter was arranged so that an explosive mixture of gases could be fired inside it. A narrow window of the same length as the bomb was provided in the wall of the chamber for emitting the light from the reaction, and a system of lenses was used for focusing an image of the window upon a highly sensitive film mounted upon a revolving drum. A pressure element was inserted at the center of the top of the bomb for measuring the rise of pressure. The pressure changes were recorded on a film that was held on a drum mounted upon the same shaft as that of the drum for recording the flame travel as is shown in Fig. 1. By developing the two films, a record was obtained which gave a distance-time curve of the flame travel and the pressure-time curve corresponding thereto. Two typical curves of

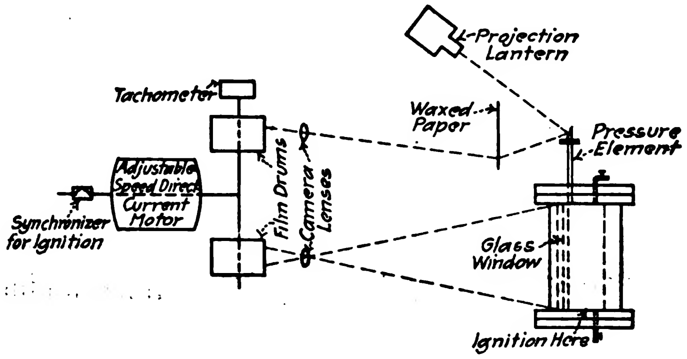


Fig. 1—Arrangement of Apparatus To Give a Distance-Time Curve of Flame Travel and the Corresponding Pressure-Time Curve

this sort are shown in Fig. 2. Ignition was obtained from a spark-plug located in the center of the bottom of the bomb. For purposes of analysis in this work, the bomb will be considered as being of unit cross-sectional area, instead of being 4 in. in diameter; this simplifies the calculation and introduces no errors. The actual pressure curves obtained by Woodbury, Lewis and Canby will not bear the scrutiny of this analysis, due most likely to improper calibration. Mr. Woodbury concurs in the belief that improper calibration of the pressure element may easily have been possible, as accurate pressure measurements were considered secondary to the photograph-

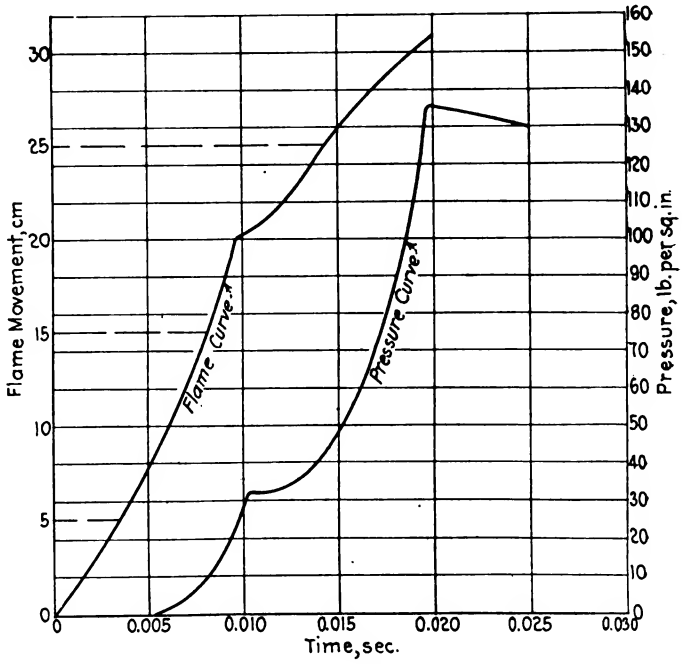


Fig. 2—Typical Distance-Time Curve of Flame Travel and the Pressure-Time Curve That Corresponds to It

[1] M. S. A. E.—Chief Engineer, fuel section, General Motors Research Corporation, Dayton, Ohio.

[2] See The Journal, March, 1921, p. 209.

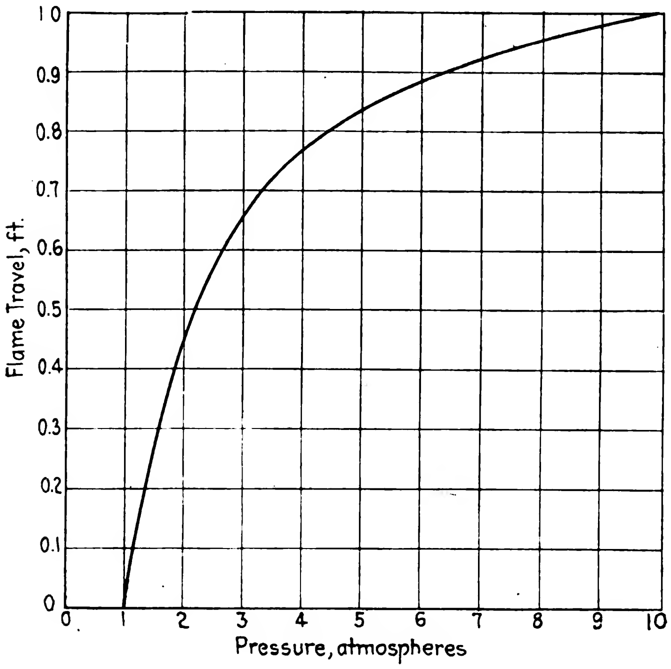


Fig. 3—Curve Showing the Relation between Flame Travel and Pressure

ing of the flame-front. I have therefore taken the liberty of substituting a "typical" curve for an "actual" curve in Fig. 2, to avoid incongruous results.

Relation of Pressure and Mass Burned to Flame Travel

The first essential in this analysis is to derive the relation of the pressure to the flame travel. This derivation is very simple; it is simply necessary to refer the two curves of Fig. 2 to each other, making allowance for the transmission of pressure from the flame-front to the pressure element at the velocity of sound. This result is plotted in Fig. 3.

The next step in the analysis is to obtain the relation between flame travel and the percentage of gas burned. This is obtained by considering the compression of the unburned portion of gas in advance of the flame-front. This gas either compresses adiabatically or receives heat from some source. The time is entirely too short for any appreciable interchange of heat with the walls of the container, the only possible change of total heat being therefore by radiation from the luminous portion of the charge. Infra-red spectroscopic investigations do not show any great absorptive power of the unburned portion. There is, of course, some absorption, but it is altogether negligible for present purposes. We are therefore fully as well justified in assuming that this gas compresses adiabatically as we are in assuming the practical existence of adiabatic compression itself.

We can now proceed. The volume of the unburned portion at any instant is established by the position of the flame-front; the pressure corresponding thereto is obtained from Fig. 3. The original pressure and specific volume of the charge are known; so, by using the equations of adiabatic compression, we can calculate the quantity of unburned charge, which, by difference, gives us the total quantity of charge burned. This is graphically represented as Curve B, in Fig. 4.

Before proceeding with the main discussion, it is well to point out that this method of analysis makes it possible to determine the thermal behavior of the hot gas at the rear of the flame-front, which is also being compressed, and to determine the nature of this compression. We are justified in making no assumptions regarding this gas except that the general equation for its compression should be of the type $PV^n = C$, where n is always less than the ratio of the specific heats. To investigate this equation properly, it will be necessary to have much more accurate data than are now available. But we are able from the data at hand to predict that n is variable in the equation $PV^n = C$, and a function of flame travel, x. A critical study of $n = f(x)$ undoubtedly will throw much light on the questions of after-burning, dissociation and heat rejection to cooling systems. These subjects form no part of the present paper, which is concerned only with the physical behavior of the gases, and further discussion of them must be left to a later date.

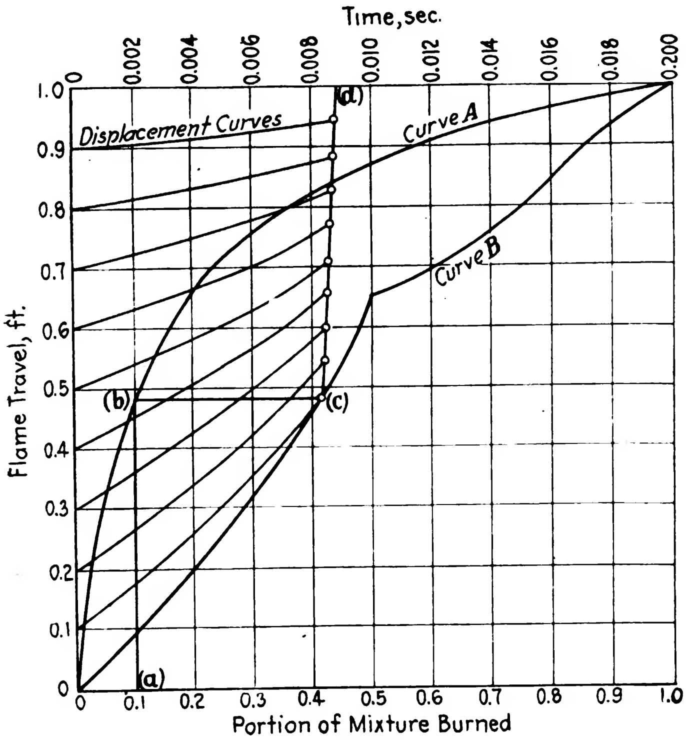


Fig. 4—Displacement Curves Showing the Relation of the Mass Burned to the Flame-Front Travel

Derivation of Displacement Diagram

A very interesting diagram can now be derived. If a flame-front photograph be plotted on the same coördinate sheet, Curve B in Fig. 4, and the corresponding relation of mass burned to flame-front travel, given by Curve A in Fig. 4, it is possible to determine the time and place that a certain mass-particle burns. For example, to determine at what point on the flame-front curve a particle that was 0.1 of the way up the bomb before ignition undergoes combustion, we start at a, which represents 0.1 of the total mixture by weight, and draw a vertical line until it intersects Curve A at b. From this point we draw a horizontal line until it intersects Curve B at c. Thus, c is then the point at which a particle with an original position of 0.1 is undergoing combustion; and, if the distance from c to d be divided into nine equal parts, the angle of this line being laid off with relation to the velocity of sound, it will give the corresponding positions of particles at 0.2, 0.3 and so on. Exactly the same procedure can be employed for determining the positions of particles at the rear of the flame front, and

the result is the displacement diagram of the particles during total combustion that is shown in Fig. 5.

Study of Displacement Diagram

The displacement diagram thus developed is plotted between the coordinates of distance of flame travel and of time. The velocity of a particle at a given point can be determined from such a diagram by measuring the tangent of the displacement curve. It is this fact that makes it possible to determine the causes of many of the phenomena that were first brought to light by the work of Woodbury, Lewis and Canby. For example, there is a vibratory condition in the gases following complete combustion, which is shown in Fig. 6 and exhibits itself as successive light and dark bands. It was demonstrated by Woodbury, Lewis and Canby that these light and dark

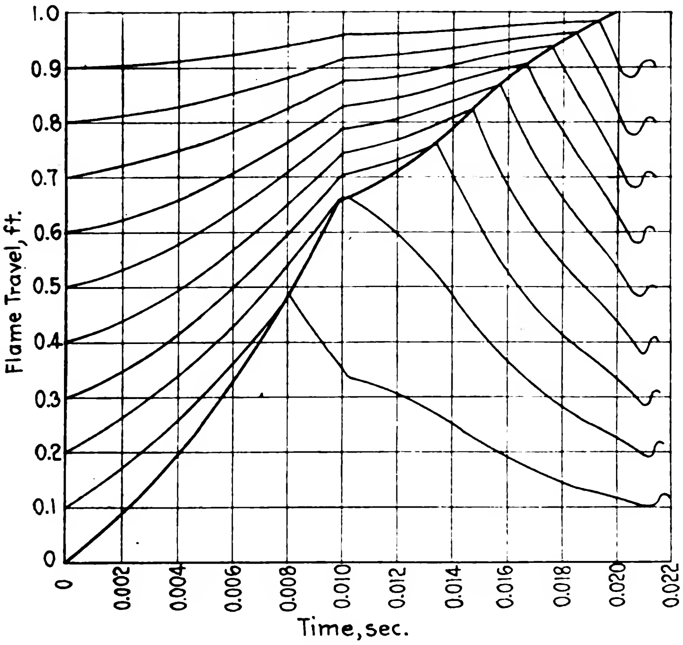


Fig. 5—Displacement Diagram of the Particles during Total Combustion

bands corresponded to a vibratory movement on the pressure record. The expansion line of an indicator-card from an engine shows precisely the same thing, as illustrated in Fig. 7, and is thus proved to be due to a surging of the gases. The displacement diagram gives a complete explanation of the mechanism by which these "surges" are set up. It will be observed from the diagram that, after the flame-front has reached the end of the bomb, the mass-particles have a rearward velocity. Since these particles have inertia, surging consequently results as is indicated in Figs. 5, 6 and 7. The pressure of the surges can be calculated.

Another very interesting disclosure is the condition resulting from the break of the flame-front curve, called the "point of arrest." Sudden changes occur in the velocities of the mass-particles at the point of arrest, this being evidenced by the sharp breaks in the displacement curves. Because of these changes in velocity and the fact that the particles have inertia, wave motion should result. The reproduced photograph in Fig. 6 shows that this is the case.

A further point of interest is the bright flash on the photograph extending from a point at approximately the position of the flame arrest toward the bottom of the bomb. This has heretofore been interpreted as evidence of a recombustion running *rearwardly* through a portion

Fig. 6—Proof of the Existence of Vibratory Conditions in the Gases Following Complete Combustion Is Afforded by the Presence of the Successive Light and Dark Bands in a Photograph

of the mixture that remained unburned during the passage of the flame-front. But the displacement diagram in Fig. 5 shows conclusively that this is not the case; because, if it were due to a chemical reaction, it could not remain stationary with respect to the mass-particles, but would be forced to travel through them. On the other hand, if it were a point of extreme luminosity, it *would* remain stationary with respect to the mass-particles. Since this last is precisely what does happen, it proves that the bright flash is simply a portion of the burned mixture that is more luminous than the adjacent material.

Pressure in the Flame-Front

Attention is called to a very interesting fact that the displacement diagram in Fig. 5 gives us, which deserves serious consideration because it is a new thought about flame propagation. If the path of any mass-particle be followed on the diagram, it will be observed that the particle has an upward velocity just before it is burned; but, immediately after its combustion, the same particle has a downward velocity. In view of the facts that the particle has mass and that its velocity has been changed, a force must have been operating in the direction of the change of velocity. In a space filled with gas alone, the only forces that can be operating are such gas pressures as may be due to unequal distribution of pressure within the container. It is possible to determine just what the pressures in the flame-front are by using some equations of flow; this is explained in Appendix 2.

Fig. 8 shows a curve of these calculated pressures in the flame-front during the flame travel. The pressure shown at any point is the difference between the pressures of the unburned and the burned portions of the charge, the unburned portion being at the higher pressure. It is interesting to note that this pressure is merely nominal through the early stages of the reaction; but, just before the point of flame arrest, it has become an appreciable quantity. I wish to point out that the pressure differential would have become enormous if the flame-front had not been "arrested." This consideration will be referred to later in this discussion.

The next item of interest that can be derived from a displacement diagram is the reaction velocity of the combustion. The reaction velocity is a value representing

Fig. 7—Photograph of an Indicator-Card Obtained from an Internal-Combustion Engine Which Shows Evidence of Gas Surges Similar to Those Illustrated in Fig. 6

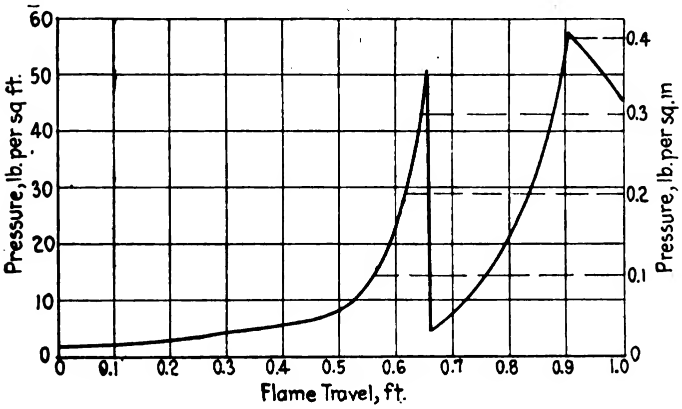


FIG. 8—CURVE OF CALCULATED PRESSURES IN THE FLAME-FRONT DURING FLAME TRAVEL

the number of molecules entering into combustion in a unit length of time. It can be obtained by scaling the upward velocity of a mass particle just before combustion, subtracting the value so obtained from the velocity of the flame-front, and multiplying the remainder by the density of the unburned gas. This is discussed in Appendix 3. The actual reaction velocity is shown in Fig. 9.

It is unfortunate that the du Pont apparatus gave the "flame arrest" phenomena, which we feel must be attributed solely to a harmonic condition of the bomb, as otherwise it would have been possible to continue the reaction-velocity curve to the end of combustion, then to have plotted this as a function of the pressure and to have derived the exponential equation of their relationship. With this information it would be possible to tell exactly just how the various molecules and atoms concerned were behaving during combustion. Unfortunately, the flame

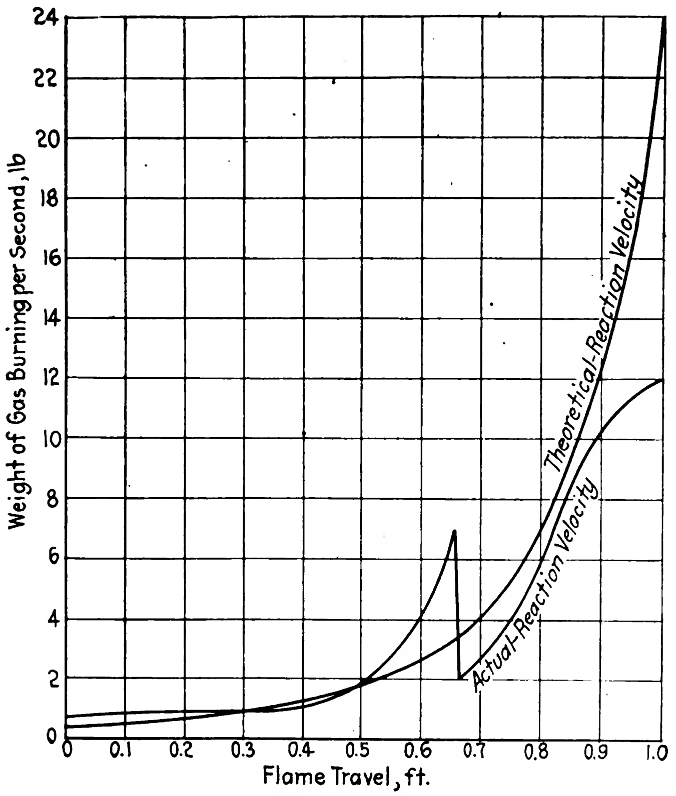


FIG. 9—CURVES SHOWING THE ACTUAL AND THEORETICAL REACTION VELOCITIES OF COMBUSTION

arrest prevents this most interesting analysis and we must wait until this harmonic condition is removed.

GENERAL COMMENTS

I wish to emphasize that the pressure differential at the flame-front suggests itself very strongly as the physical cause of the effect that we know in practice as the fuel knock or, more properly, as detonation. If this point is accepted, calculations can be carried further to illustrate practically all of the phenomena which accompany detonation.

We hope to continue these investigations to further conclusions and to present the results obtained from time to time as the various stages are completed.

APPENDIX 1

CALCULATION OF THE RELATION OF PRESSURE TO FLAME TRAVEL

To calculate the relation of pressure to flame travel, we proceed in the following manner. Fig. 10 is a dia-

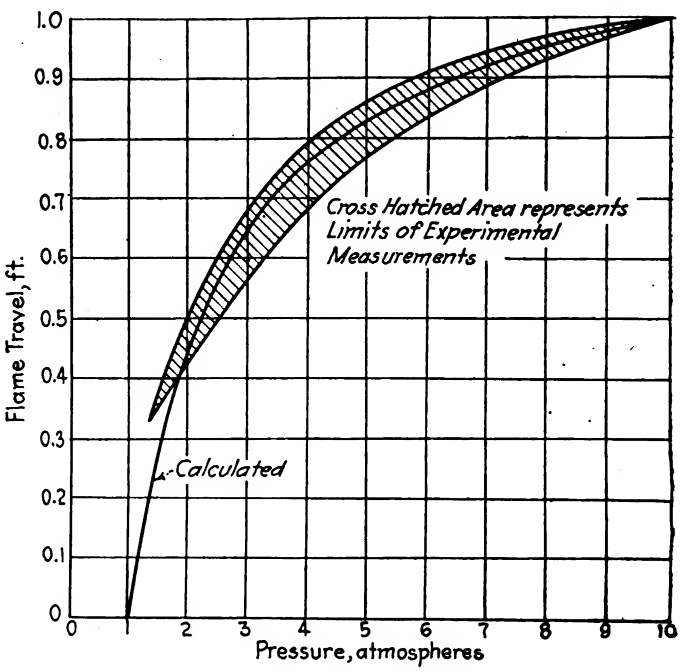


FIG. 10—CURVE OF THE RELATION BETWEEN FLAME TRAVEL AND PRESSURE IN A CLOSED BOMB

gram of a closed bomb with a flame-front at a distance x from its origin.

Let

x = the distance the flame has traveled
B = the original volume of gas that has expanded to x
p = the instantaneous pressure
P_1 = the original pressure = 1 atmosphere

By simple adiabatic relationship,

$$\frac{p}{P_1}=\left(\frac{1-B}{1-x}\right)^{\gamma}$$

and

$$P_1=1$$

Then,

$$p=\left(\frac{1-B}{1-x}\right)^{\gamma}$$

This can be transposed to

$$B=1-(1-x)p^{1/\gamma}$$

By using values from Curve A in Fig. 4, we can derive values for B and plot Curve B of Fig. 4.

APPENDIX 2

Calculation of Pressure Drop in the Flame-Front

To calculate the pressure drop in the flame-front, let us consider the flame-front as being stationary and that the gases pass through it. This is perfectly allowable for instantaneous considerations such as the present. We then have the condition shown at the left of Fig. 11, where the velocity, v, is the velocity of the particles entering combustion with respect to the flame-front. Let dm be a small mass of gas in the flame-front, of a thickness ds and an area equal to unity. Then the pressure change is equal to $-(P_1 - P_2)$, which is equal to $-dp$. It will be observed that, as dm passes through the flame-front, it increases its temperature and consequently its volume. An increase of volume requires an increase of velocity, and an increase of velocity means a pressure drop to secure the necessary acceleration. Since force equals mass times acceleration, or $F = MA$, we have, for unit area, $-dp = dmA$. But

$$A = \frac{dv}{dt}$$

where

$v =$ the velocity

Then,

$$-dp = dm\frac{dv}{dt}$$

It will be observed that

$$dm = \frac{ds}{gV}$$

where

$V =$ the specific volume
$g = 32.2$

Substituting for dm we get

$$-dp = \frac{ds}{gV} \times \frac{dv}{dt}$$

But

$$\frac{ds}{dt} = v,$$

Then,

$$-dp = \frac{vdv}{gV} \qquad (1)$$

Let W be the weight of gas entering the flame-front, expressed in pounds per second. Here W is treated as a constant on the assumption that during the passage of the element dm through the flame-front no change in W occurs. Of course, this is not strictly true. The right to assume constancy depends largely upon the magnitude of the actual change of W during this time, which will depend upon the length of time the element dm is in the flame-front and this, in turn, depends upon the thickness of the flame-front. Woodbury, Canby and Lewis have established that the maximum pressure-rise occurs as nearly coincidently with the end of the flame travel as it is possible to measure. If the flame-front were of any appreciable thickness, this condition could not exist. I have some inconclusive evidence of another sort, the details of which are unnecessary here, that indicates a thickness of flame-front during detonation of less than 1/32 in. I believe this to be a safe value to take for the flame-front thickness. It introduces, at the point of arrest, a deviation from constancy of only 1 per cent for W. Under these conditions the assumption is justifiable. Since the bomb is of unit cross-section, $v = WV$; then $dv = WdV$. Substituting in equation (1) for v and dv, we obtain

$$-dp = \frac{W}{g} \times WdV = \frac{W^2}{g}dV$$

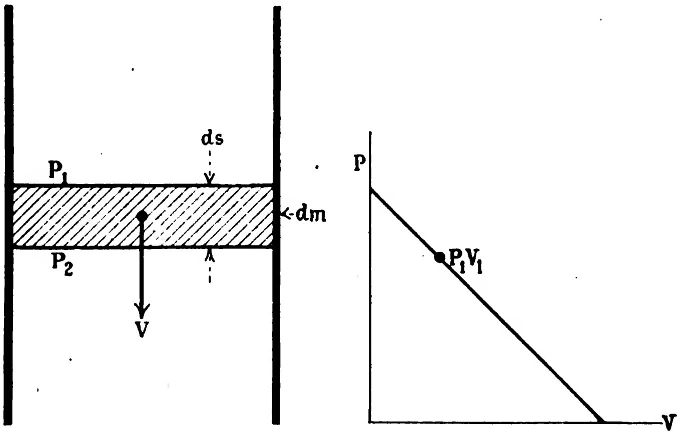


Fig. 11—Diagram (at the Left) of the Relations Existing in the Flame-Front Where the Gases Are Considered as Passing through a Stationary Flame-Front and (at the Right) Showing How the Equation for Pressure Drop Becomes a Straight Line under Certain Conditions

By integration between the limits P to P_1 and V to V_1 we obtain,

$$P_1 - P = \frac{W^2}{g}(V - V_1) \qquad (2)$$

In equation (2), P_1 and V_1 are constants; P and V represent the pressure and the specific volume. This equation becomes a straight line on the pressure-volume diagram, as shown at the right of Fig. 11.

We can now proceed to apply this formula to calculate the pressure in the flame-front. For example, considering a particle having an original position of 0.200 that burns at position 0.663, at that time it has a velocity with respect to the flame-front of 11 ft. per sec., which we obtain by scaling the displacement diagram. The original specific volume of the gas is 12 cu. ft. per lb. The specific volume of particle 0.200 at position 0.663 *before* combustion is $12[(1 - 0.663) \div (1 - 0.20)] = 5.06$ cu. ft. per lb. The specific volume of particle 0.200 at position 0.663 *after* combustion is $12(0.663 \div 0.200) = 39.9$ cu. ft. per lb. Hence, the weight-rate of gas flowing is $11 \div 5.06 = 2.17$ lb. per sec. Substituting these values in equation (2), we have $P_1 - P = [(2.17)^2 \div 32.2](39.9 - 5.06) = 5.09$ lb. per sq. ft.

APPENDIX 3

Derivation of the Actual-Reaction Velocity

To derive the actual-reaction velocity, take the velocity of the particles with respect to the flame-front, as obtained from the displacement diagram (Fig. 5) and divide this by the specific volume. We obtain thereby a figure representing the number of molecules passing into the combustion per unit of time. This is simply W, the weight of gas passing into the flame-front per second, which was derived in Appendix 2. There values are plotted against flame travel in the curve of actual reactional velocity shown in Fig. 9.

As an extrapolation, for the reaction velocity of particle 0.0, we have burned 0.195 cu. ft. in 0.01 sec. at the point of flame arrest, and 0.195 cu. ft. $\div 12 = 0.01625$ lb. Then the average reaction-velocity has been $0.01625 \div 0.01 = 1.625$ lb. per sec. Therefore, the initial-reaction velocity should be in the neighborhood of 0.8. We can assume this for purposes of plotting and then check by the integration of the curve. This value checks well enough for all practical purposes.

THE DISCUSSION

PROF. AUGUSTUS TROWBRIDGE:—Mr. Midgley shows in Fig. 5 exactly what takes place in a way that has perhaps never been presented before. The obvious thing about this diagram is that at the flame-front there is a real reflection, so to speak, of the particles that have been moving forward, and at the flame-front they are turned around and move in the opposite direction.

I do not doubt that the first man who saw the phenomenon of the flame arrest was greatly puzzled. Apparently, the flame runs down the tube toward the closed end; then it appears to come backward; then it goes ahead, wavers again, then goes forward; then wavers two or three times and may become extinguished at that stage. In particularly narrow tubes it often does become extinguished; however, if it does not, it always proceeds with something approaching detonation speeds, speeds inordinately greater than those shown in Fig. 5. One thing that occurs to me is that in the conditions shown in Fig. 5 we are probably far from those of the detonation stage. If the experiment had been carried out in a tube of narrower bore and greater length, I should judge that there might have been more than one of these stages of flame arrest, followed by a curve which would be almost a vertical line.

It is highly desirable that accurate data be collected so as to permit a rigid test of the validity of the relationship $pv^n = C$ to the rear of the flame-front. Mr. Midgley states that the interpretation of the data already at hand suggests that n is not a constant. If this be so, the process can hardly be described as adiabatic. If n is variable, the process is one in which heat is being lost by the system and so a knowledge of how n varies with the time or with the position of the flame travel may throw light on the manner of the heat loss.

I recorded some results of experiments about a year ago, at a meeting of the National Academy of Sciences, regarding changes of mixture, content and pressure. I am reasonably certain that there is absolutely no change possible in flame speed brought about by change of external pressure. If conditions are started at a pressure of 1 atmosphere, we have a certain speed and we get practically the same speed at 10 atmospheres. Neither do changes in gross temperature outside the cylinder do very much. The speed is very nearly the same, whether it starts hot or cold. The conclusion is that we cannot get close enough to the real thing. With this wave-front with the change in pressure, the temperature at that point is highly effective in changing the flame; but we must do it chemically, physically, through reagents that get in close, such as sound-waves and things of that sort, and not from the outside.

I applied the experiments to very long tubes compared to those used in Mr. Woodbury's work and observed the very curious phenomenon that in practice, in closed-bomb experiments, this flame wave is very much longer than we imagine. I have some fairly conclusive data that we can actually fire a mass of coal gas and air in the ratio of 14 to 1, and can fire that mass much more rapidly by starting it off 22 in. away from the bomb than by firing it in the bomb itself. We get complete combustion more quickly by getting past this stage of wavering, and shooting the charge in then. One will find that the pressure-rises actually come more rapidly by getting off farther, so that this stage of wavering is passed, and then coming in at almost detonation speed; that is, one gets higher gas-flame speeds from detonation from a greater distance.

C. A. WOODBURY:—Those who have spent much time in theorizing on flame propagation realize the necessity for a simplification of the conception of what takes place when flame travels across a cylinder-head. The displacement diagram that Mr. Midgley shows in Fig. 5 is a contribution along that line. It will simplify our ideas of just what happens when we ignite an explosive charge of gas and air and the flame travels across the cylinder. But there is one point which is not clear to me in regard to his conception of this flame movement. He speaks of the difference in pressure between the area ahead of the flame and that back of it, and that it is this difference in pressure that is responsible for the rapid movement of the particle from the flame-front when once released. This particle is ahead of the flame front before the flame hits it and ignites it, and of course it must be behind it after it is burned. When this flame moves forward and attacks a particle of gas and burns it, that particle of gas must expand, and something must happen to it. The heat units liberated require that this gas particle expand, but that expansion will develop pressure both ahead and back of the flame-front. The particles ahead will be pushed forward still farther and the particles behind will be pushed back still farther, the extent of the movement depending in both cases upon the relative compressibility of the two sections of gas. I cannot see that this needs the assumption that we must have a pressure differential between the areas ahead of and behind the flame-front.

THOMAS MIDGLEY, JR.:—It is because of the law of nature that force equals mass times acceleration. The particle has mass, and it is accelerated toward the rear of the bomb. Hence, there must be a force acting. The only force that can be acting in the space that is filled with nothing but gas is a pressure differential in the gas. The region within which this pressure differential exists is actually in the flame-front. The gas on the forward side of the flame-front in Fig. 5, the point of flame arrest, has about 0.3 lb. per sq. in. higher pressure than the gas back of the flame-front, in order that the flame may be enabled to expel the products of combustion.

The total pressure developed is a large factor in comparison with the pressure differential. The pressure in the gas does not all become pressure in the flame-front by any means. The pressure differential in the flame-front is only the small part that is necessary for the flame to get rid of its ashes. It is an automatic ash-remover by which the flame is enabled to throw the reacted mass-particles to its rear.

MR. WOODBURY:—I conceive that at the point a in Fig. 5 the downward velocity of that particle away from the flame-front is greater than the upward velocity of particle b in the direction c d, but what is the condition down at the bottom of the bomb? Would not the downward velocity of particle a be less than the upward velocity of particle b, as indicated in Fig. 13?

MR. MIDGLEY:—It makes no difference whether the velocity to the rear is greater than the velocity in front of the flame-front; the fact remains that the direction has been changed. The pressure differential does not apply until the flame-front has had time to get the particles ahead of it started in motion, so that at the bottom, or just at the time of ignition, the pressure differential naturally does not exist. I feel that this disclosure of a pressure differential in the flame-front is the outstanding result of this analysis so far. It is a thing no one has guessed, so it is hard for some of us to conceive.

B. B. BACHMAN: — In considering the Woodbury, Canby and Lewis diagrams of flame movement and the

pressure increment, upon which some of this analysis is based, there is a lag apparent in the time between the initiation of the flame, which starts at zero time, and the initiation of pressure, which is some time later. The pressure curve in Mr. Midgley's analysis apparently allows for some discrepancy that may exist, due to the fact that his theoretical curve of pressure coincides closely with the observed pressures.

In considering the method used in the original investigation, I note that the recording of flame movement is entirely by transmitted light; whereas the rise of pressure, of necessity, must first be transmitted through the contents of the vessel at the velocity of sound before it reaches the pressure element whence the record is transmitted to the film by light rays. This condition raises the question in my mind as to whether the difference in time between the appearance of flame and the initiation of pressure is due to the method of obtaining the record. Have the experimenters done anything to determine what loss in time, if any, exists in transmitting the pressure from the point of inflammation to the instrument?

MR. MIDGLEY:—I think there is no question in the mind of anyone who is willing to think small enough that, with the initiation of the flame-front, there must be a coincident initiation of pressure. But the experimental work does not show it. The theoretical pressure-rise of this flame-front is a curve something like Curve *A* in Fig. 5. It is evident that the flame can travel a considerable distance before there is any appreciable rise in pressure. Although there has been a rise of pressure, it is only a fraction of a pound, due to the fact that only a very small portion of the gas has been burned. One can see that only 0.1 of the gas has been burned when the flame travel is one-half way down the bomb.

MR. WOODBURY:—We did put the pressure element on the base of the bomb. I think it was for the purpose of checking up with the arrest in the flame. It was not simply a surge and the rate of gas burned was exactly the same, even though the flame seemed to stop. We had an idea that the gas was pouring through there. I am not sure whether it checked up with the point that the first indication of the pressure registered.

A. C. BIGELOW:—Was the ignition directly in the bottom of the cylinder?

MR. MIDGLEY:—Yes.

MR. BIGELOW:—Do you consider that there would be very much of a change in the shape of the diagram if that ignition had been on the side?

MR. MIDGLEY:—There might have been; I do not know. This whole pressure differential that is calculated in the Appendices of this paper is on the basis of a bomb of constant cross-section. If we upset the initiation and have a flame-front of a distinct angle, I do not know what the result would be.

G. W. SMITH, JR.:—Have you formed any conclusions as to how the action might be modified for substituting gasoline for acetylene gas?

MR. MIDGLEY:—I have an idea that it would slow down somewhat. Otherwise the diagram would be unchanged.

MR. WOODBURY:—I think that would be the case. This curve of Mr. Midgley's is a typical curve. I think it makes little difference whether that is from and at ordinary temperatures or a permanent gas. That seems to be a typical behavior; only the average rate of the flame would vary.

A MEMBER:—Was anything done in these experiments to use a different moisture-content in the air that was united with these gases for combustion, with the idea in view as to whether, if the moisture-content there contained hydrogen from water, it would have anything to do with the quality of the light bands, if it should reach the firing point of the hydrogen?

MR. MIDGLEY:—I think nothing was done in regard to the moisture-content in the experimental work. There is so much else to be done in that sort of experimentation that this has not been done.

Will Mr. Woodbury subscribe to my belief that we can work more intelligently with this analysis in mind?

MR. WOODBURY:—Without a doubt.

MR. MIDGLEY:—Heretofore, experimentation on flame propagation has consisted more or less of setting up something, watching it burn and then drawing conclusions. There is a little matter of relativity mixed up with it. As we photograph with respect to a fixed bomb, the gaseous molecules in which are moving, the only thing that counts is how fast the molecule is moving with respect to the flame-front. That is, the important thing is a relative velocity of flame-front to molecular movement. Failure to appreciate this point has rendered valueless the large volume of the experimental work of just this sort that has been done.

HARTE COOKE:—In regard to Mr. Midgley's paper, in the old steam-engine days we had a very peculiar pause in the indicator-card steam-line for that type of engine in the low-pressure cylinder. The pressure would come up and the admission would begin; then, strange to say, there would be a pause. We had always thought that this pause was caused by some irregularity in the indicators. We then took cards on the low-pressure cylinder with the high-pressure indicator-motion, bringing the admission in the middle of the card where it could be seen. There was then no question that the pause existed but, at first, so far as we could see, there was no reason it should exist. The valves were opening very rapidly and the piston was standing still. However, as nearly as we could determine, that was at about the place where the temperature of the entering steam became higher than the temperature of the cylinder-walls; it became conscious, so to speak, of the fact that the cold cylinder-wall existed. The cooling effect was so great that the steam was condensed as fast as it came in, momentarily. Then the pressure came up normally. That is interesting, as this pause was very much the same as the pause Mr. Midgley has shown.

THE STUDENT

THE present remarkable position in applied science and in industrial trades of all sorts has been made possible by men who did pioneer work in chemistry, in physics, in biology and in physiology, without a thought in their researches of any practical application. The members of this higher group of productive students are rarely understood by the common spirits, who appreciate as little their unselfish devotion as their unworthy neglect of the practical side of the problems. —William Osler.

INTERNAL-COMBUSTION ENGINE FUELS

THE paper on Internal-Combustion Engine Fuels printed in the March issue of THE JOURNAL on page 187 was read by Professor Norman before the Minneapolis Section somewhat over a year ago. As there was nothing in the paper to indicate this, some readers may have been surprised to find certain discrepancies between the figures used and those given by Dr. J. E. Pogue and others in publications of a later date.

Alcohol for Motor Fuel

Research Topics and Suggestions

The Research Department plans to present under this heading each month, a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

NEARLY every general discussion of the problem of motor fuels includes some reference to the use of alcohol for this purpose, either alone or blended with other materials. Engineers have recognized from the beginning the special advantages of alcohol, as attested by the large number of papers and reports on this subject extending from about 1900 to the present time. An exhibition of alcohol engines was held in Paris in 1902. The use of alcohol for power purposes had been developed in Germany under direct Government encouragement to an important industry by 1905. Much of the best and most important experimental work with alcohol has been confined to slow-speed heavy-duty stationary engines, although some attention has been paid to automotive engines.

The special reason for bringing the subject up at this time is not the immediate interest in the use of alcohol as a fuel in this Country in the near future, but rather the trend of development in other countries that may affect very materially the automotive industry here. So long as gasoline is available in the quantities desired at a price that is within reason, the use of alcohol is not likely to become general in engines built specially for gasoline. Moreover, alcohol probably could not be produced in the United States in sufficient quantity to affect the fuel situation here greatly, at a price that would compete with gasoline, unless a very acute shortage of the supply should develop.

There are, on the other hand, localities where quite the opposite condition occurs, the demand for motor fuel being comparatively small, the potential supply of alcohol large and the sources of gasoline distant and controlled by outside interests. This is true to a considerable extent in Cuba, the Philippines, Hawaii and in much of South America, all of which territories are large potential users of the products of the automotive industry. In Cuba at present it is reported that half the motor vehicles are using alcohol. If true, this shows a remarkable demand for a substitute for gasoline as now marketed there. But it may also be a menace to the industry. Existing stock passenger-cars, trucks and tractors are not adapted to the use of alcohol without some important modifications. Its general use under these conditions may lead to difficulties that will tend to discredit the vehicle in which it is used. Our powerplants as they exist today are the result of careful and detailed adaptation to the use of a certain fuel, gasoline. To be equally successful with another fuel of very different character will require another period of adaptation.

In spite of the difficulties and inconvenience that may result from the use of alcohol in present stock engines, both alcohol and its mixtures with gasoline are excellent fuels possessing many important advantages over gasoline. Moreover, the use of them is an economic necessity in some of the countries mentioned above.

Ultimately, the ability of the United States manufacturer to market automotive equipment in the countries must depend upon his producing such equipment adapted to the use of alcohol fuel. The special problems involved in the use of alcohol are many and can only be suggested here, with the hope that some of them at least will be the subject of systematic research and development by some of our laboratories.

The main questions to be considered in the utilization of any new fuel in automotive engines of present types may be stated briefly as follows:

(1) Metering of the charge
(2) Distribution to and in the cylinder
(3) Combustion characteristics within the cylinder
(4) Performance of the engine as regards power, flexibility, and economy
(5) Incidental or secondary effects of the fuel on the engine and accessories

In all these respects alcohol differs so radically from gasoline that a comprehensive research program must include consideration of all of them.

Metering of alcohol, if done in a conventional type of carbureter, will involve differences only in the size of orifice or the metering head necessary for the correct air-fuel ratio. Alcohol in general requires a larger orifice because of both its viscosity and the larger volume used per cubic foot of air.

Distribution of the charge with alcohol as fuel should present no serious difficulties, provided the same degree of evaporation is maintained as with gasoline. Since the boiling-point of alcohol is lower and the heat of vaporization much higher, the amount of heat required in the manifold is a matter requiring experiment. Some recent results show that more heat is required for burning alcohol. The temperature and the amount of heat required to produce a suitable alcohol-air mixture calls for investigation.

The combustion characteristics of alcohol differ radically from those of gasoline. One of the main differences is that starting is more difficult with alcohol than gasoline. Some of the reasons have been pointed out by R. E. Wilson and Daniel P. Barnard.[1] The starting requirements of alcohol must be investigated.

Fuel knock with alcohol will not occur except at very high compression-pressures. This means that the compression-pressure for alcohol can and should be much higher than for gasoline. Pressure all the way from 110 to 180 lb. have been recommended. How much higher this should be for best results is a subject for research and trial.

The range of combustibility is much different from that of gasoline. This is a relation that has a very important bearing on possible fuel-economy. The necessity of using throttle control instead of controlling the fuel supply alone as in the Diesel engine means low efficiency at part throttle. Alcohol is said to ignite at much lower mixture-ratios, so that it may be possible to adopt a method of control by varying the fuel supply alone. This would increase greatly the economy at part load, and might offset the inherent high consumption of alcohol per horsepower. This subject particularly requires laboratory research to determine the limits of combustibility over the full range of pressure and temperature, as well as to show the possibility of controlling power with alcohol by varying the fuel ratio.

The alcohol mixture-ratios that will afford maximum power and economy differ from those for gasoline. Unfortunately we have only very meager data even on the latter. Alcohol mixtures give maximum power when excessively rich; more so than gasoline. The mixtures for maximum economy have

[1] See THE JOURNAL, November, 1921, p. 313.

not been well determined; more knowledge here is necessary for the best development of alcohol engines.

Carbonization with alcohol is said to be very small indeed. Is this a fact? The amount of discussion that has been devoted to the subject of carbonization due to lubricating oils would lead one to suppose that the fuel has not much to do with the matter; yet carbonization was not troublesome until motor gasoline acquired an end-point of about 370 deg. fahr. There is room for some real study of the problem of carbonization with alcohol fuel.

Ignition temperatures of alcohol-air mixtures have been studied by Professor Dixon, of Manchester University, as well as other investigators. This is a phase of the range of combustibility previously mentioned. The subject is one, however, that could be taken up further to good advantage by some university laboratory. The results should be of value, as should the research training afforded research assistants working on such a problem.

The rate of combustion in alcohol mixtures is said to be much slower than in gasoline mixtures. This has an important bearing on the design of alcohol engines. The evidence on this point is conflicting; moreover, the direct experimental results on ratio of flame speed under conditions comparable to those in an engine are few. It would be very much worthwhile for some laboratory interested in the subject of flame velocity to include alcohol mixtures in its study.

The general performance characteristics of engines using alcohol fuel have been studied to some extent, but mainly at full load. Cylinder-head design and spark-plug location are probably important. More power can be obtained sometimes from the same cylinder with alcohol than with gasoline, at the same compression, and a still greater excess at the higher compression-ratios permissible with alcohol. Part-load performance should be studied as regards thermal efficiencies and mixture requirements as well as general performance characteristics.

The incidental effects of alcohol on the engine involve one feature that is particularly important. This is corrosion of tanks, pipes and fittings. The metals now used for tanks, such as galvanized iron and tinner iron, are not suitable for use with alcohol and its continued use in these tanks will usually cause trouble. Some metals, such as aluminum and monel, are not seriously affected and could probably be used with entire success. Brass used in carbureters and fittings is not very seriously affected. There is also some possibility of corrosion in cylinders and mufflers, but the data on this are conflicting. The purity of the alcohol or its freedom from certain impurities probably determines the amount of corrosion. This whole question of corrosion is in need of very careful research, as it is perhaps the most important single hindrance to success in the use of alcohol fuel.

Complete answers to the above-stated questions should permit the design of engines that would use alcohol fuel with the same degree of satisfaction as is now had with gasoline. The foregoing discussion has applied to alcohol alone, but it would apply to blends of alcohol with other hydrocarbons. In fact, such blends have some decided advantages over either fuel alone. An ideal engine should be capable of using either gasoline or alcohol or any combination of them, and of realizing the inherent advantages of each with a minimum of modification necessary in changing from one fuel to another. Such engines should be very popular in countries where alcohol is cheap and gasoline dear.

SELECTED BIBLIOGRAPHY

Fuel alcohol in Australia. *Engineer*, Sept. 21, 1917, pp. 278-279.

Great Britain — Departmental Committee on Alcohol Motor Fuel. Report on various matters concerning the production and utilization of alcohol for power and traction purposes, 1919.

Comparative fuel values of denatured alcohol in internal-combustion engines, by R. M. Strong and Lauson Stone, Bureau of Mines Bulletin No. 43, 1918.

Researches on alcohol as an engine fuel, by Harold B. Dixon. THE JOURNAL, December, 1920, p. 521.

Carburetion of alcohol, by A. W. Scarratt. THE JOURNAL, April, 1921, p. 328.

Alcohol-fuel mixtures. THE JOURNAL, October, 1920, p. 345.

Starting on alcohol. THE JOURNAL, November, 1921, p. 319.

Power alcohol and alcohol engines. *Automobile Engineer*, July, 1918, p. 188.

Survey of the chemical and physical properties of alcohol as fuel. *Automobile Engineer*, April, 1920, p. 157, and May, 1920, p. 183.

Benzol, alcohol and mixtures of these liquids with gasoline as fuels for internal-combustion engines, by Prof. G. W. Watson. *Automobile Engineer*, December, 1914, p. 376.

THE WASHINGTON CONFERENCE

THE jeopardy of war has been most assuredly driven beyond our generation. Naval rivalry with England has been stopped, with all the implications which must follow from that rivalry. The Anglo-Japanese Alliance has been abandoned. The points of friction between ourselves and Japan have been settled. The major difficulties between Japan and China have been adjusted so that good will may replace hate in the Far East. The tide of foreign aggression on the frontiers of China has been turned back. The "open door" of commerce and industry of all nations in China has at last been made effective. With all these solutions, a vast growth of malign political forces has been uprooted, which, if unchecked, would have driven unalterably to war.

With half of Europe armed on a basis that, in equal ratio, would mean a standing army of 1,500,000 men in the United States, with twice this number of reserves, there is little hope of economic progress. The economic loss in the decrease of national production and in the effect such decrease has on national finance is one of the great difficulties of Europe. Yet there is a greater loss than all this, for economic life can thrive only in an atmosphere of peace.

The first effort of the world should be to reestablish its sadly lowered standards of living, recover employment for its workers, recover income to its farmers and reestablish the prosperity of its manufacturers and merchants. The world is now, and will be for many years, short of capital with which to carry on the development of industry and commerce. America is today the remaining great reservoir of surplus capital, and we must remain strong and conserve the rightful use of this capital if the world is to recover. We shall need much of it for the upbuilding of our homes and our public utilities, stagnated today through inequalities in readjustment between industries. But our surplus even then is greater than our needs, and it would be a disaster if it were dissipated in wasteful expenditures abroad.

All loans to foreign nations that are not employed in reproductive work are a destruction of the capital. It is vital that our bankers and our investors should scrutinize the loans to which they are asked to subscribe, that they may make sure that they are to be employed for reproductive purposes or the refunding of outstanding obligations. The furnishing of raw materials, the construction of transportation facilities, public utilities and factories and work throughout the world, is a use for American capital that blesses both the borrower and the lender. The upbuilding of the rest of the world and its consuming power adds primarily to world wellbeing, but it also adds to the demands for our own labor, for the products of our own farmers and the services of our own merchants.—Herbert Hoover.

Some Notes on the California Top

By P. W. Steinbeck[1]

Annual Meeting Paper — *Illustrated with* Photograph and Drawing

THE California top is the result of a demand for a convertible enclosure that combines the desirable features of the open top with the protection needed at night or in bad weather. The history of its development is outlined and shows the evolution of a top that can be stowed or removed quickly and that has a permanent roof and glass windows. The present California top and its construction is then described and illustrated.

THE California top represents the present-day culmination of a concerted effort on the part of body engineers in this Country to produce a really satisfactory type of convertible enclosure. This particular style took its name from the Pacific State since the development of a readily convertible open car was particularly demanded in California because of weather conditions peculiar to that region. The days are generally very warm there and demand the protection of an open top with ventilation unhampered by windows. The evenings, on the other hand, are accompanied by heavy dews and a relatively large drop in the temperature which makes one uncomfortable in an open car. The car-owners seldom wished to lower their tops, disliked the saggy appearance of the folding style and demanded something more pleasing to the eye. The body-builders and designers recognized this demand for a more durable and satisfactory type of curtain and top than the customary folding type with celluloid lights, and began the development of what has come to be known as the California top. An example of the present type of top applied to a touring car is illustrated in Fig. 1.

Fig. 1—Application of the California Top to a Touring Car

Development History

The first step, taken 6 or 7 years ago, was to construct a solid frame of wood and cover it with artificial leather, using glass lights in the sides and rear instead of the customary celluloid. This top did not represent any great improvement over the one-man top. It was more rigid, to be sure, but the bothersome flapping storm-curtains were retained and were attached loosely by fasteners or buttons. Nevertheless, these tops sold well. They were something different and, since most of them were custom-built, each particular owner had an opportunity to express his own fastidious tastes in form or color. The natural result of this self-expression was a conglomeration of designs and clashing color contrasts. The beveled-edged plate-glass windows in the back and rear-quarter curtains were fantastic in shape and represented anything from a half-moon to a diamond or oval.

A few years later a top appeared that represented the next stage in the creation of the present-day California top. Its outline, shape and trimming closely resembled the type just described, but the curtains slipped or rolled up into the space between the top deck and the head-lining. They were concealed in this way when not in use and made a fairly weather-tight enclosuse when pulled down. There were several serious faults in this design, however. The curtains carried moisture into the top when rolled up after a rain-storm, causing the head-lining to become moldy and to rot. The celluloid lights were dried out due to the heat in the top; they crystallized, became brittle and were soon fogged so that vision through them was impossible. Although this type proved to be popular for a time, the body engineers soon recognized it as a mere stepping-stone to the construction of something possessing the same utility but of greater durability.

A body-builder named Gould exhibited a closer approach to the ideal convertible top at the San Francisco Automobile Show in 1919. It was meant to fulfill the Californian demand for a top with permanent roof and glass windows that could be stowed or removed quickly. In this design the windows slid back into a pocket formed in the rear-quarter window, and were concealed in this way when out of use. Fig. 2 shows the features of this design, but with the details somewhat improved over the original top built and displayed by Mr. Gould.

Present Practice

This top can be built on any touring car or phaeton open body. A set of sills is first screwed securely to the body top-rail and, from this foundation, a slatted roof construction is built up over cross-bows, the slats being 1½ in. in width and running lengthwise of the roof. In the roof there are two U-channels with a drop as shown in Fig. 2. Each glass frame has a lock fastened to the top of the frame, which slides in a U-channel and, as each frame is suspended in the U-channel, they are pushed forward until they drop in the U-channel depression. The glass frame then drops into its position and becomes rigid. There is a separator on the sill that holds the frames apart. The space between the glass frames has two rubber strips to keep out the weather. Each glass frame can be pulled forward, or to the rear quarters, by attached handles. When the glass frames are in the rear quarter, they are held by a spring that presses down

[1] M.S.A.E.—Body engineer, H. H. Babcock Co., Watertown, N. Y.

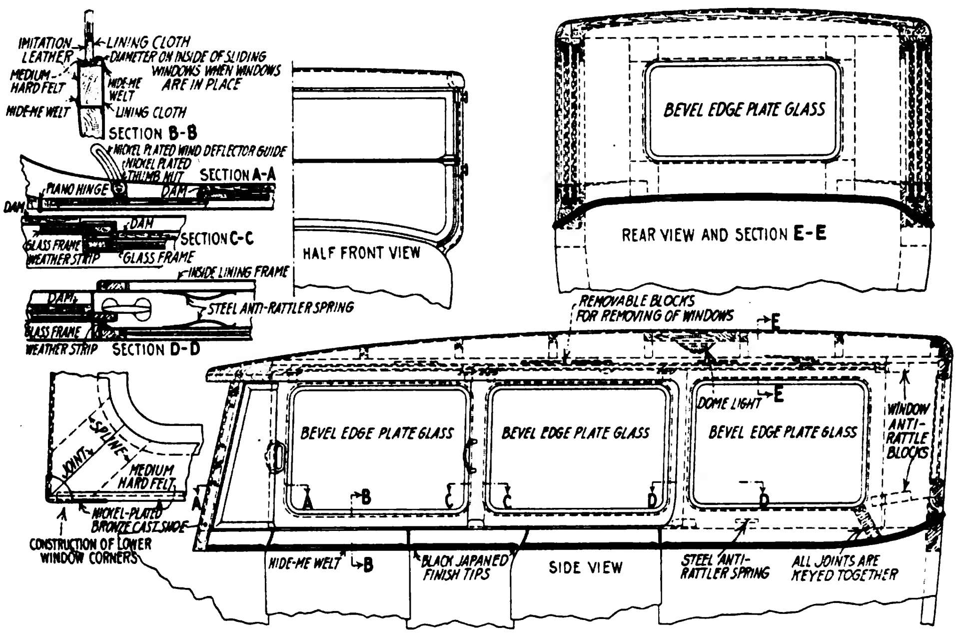


Fig. 2—Details of the Construction of the California Top

from the top and prevents any rattle. The top is covered with the usual artificial leather or top material of the color desired and the inside is trimmed with cloth or slip-lining material in a manner similar to that used for closed-car roofs. The window frames are covered in the same way. Plate glass having beveled edges is used in the glass frames. When space permits, a glass-frame wind-deflector is hinged to the windshield which can be opened or closed by a quadrant and screw. A dome light equipped with a switch is installed in the roof. This type of California top is a distinct innovation in that it is a summer and winter top combined. It could be developed on a production basis and reduced in price to fit in and sell between the sedan and the touring-car types.

THE DISCUSSION

W. C. Karns:—What provision is made on the bottom of the frames to keep the rain from blowing in?

P. W. Steinbeck:—There are two pieces of rubber fastened to the glass frames, that close the opening between the frames; on the bottom or sill there is a weather-strip on the inside of the frame that makes a water-tight job.

Mr. Karns:—Do those glass sides open with the door or must one slide the glass?

Mr. Steinbeck:—One must slide the glass. If one is inside the car, the first movement in getting out of the door would be to push the glass back.

Mr. Karns:—I should think that would be objectionable.

Mr. Steinbeck:—With a front and rear door and a space between them, as shown in Fig. 2 of my paper, only two windows are required to fill that space. Therefore, the windows must overlap the space between the two doors. Hence, the windows cannot be of the same size as the opening of the doors. It is a very easy matter to pull the glass frame back and get out. It moves in either direction. In driving, there are times when there is a strong wind blowing from one side. The driver is protected by the windshield and the deflector, but the occupants in the rear seat get the whole force of it. Even on a nice day with the wind blowing hard, they are uncomfortable; if one window frame is slid into position, it will protect the rear passengers.

Mr. Karns:—I think that is an objectionable feature.

Mr. Steinbeck:—It is not so objectionable as trying to unbutton or undo a fastener when it sticks, perhaps pulling the whole fastener off. Compared to entering a car with curtained sides, when the curtains are buttoned down tight, and especially after they have shrunk, I think the improvement would be appreciated.

G. W. Kerr:—How does the glass on the front door open?

Mr. Steinbeck:—It slides on a channel. One glass hangs on one channel and the other glass on another channel. They slide past each other. The handles are flush.

Mr. Kerr:—How is the car ventilated?

Mr. Steinbeck:—Through the wind deflector and by opening the windows.

Chairman E. G. Budd:—Is the rail that is used fixed independently into each door?

Mr. Steinbeck:—Yes, but it is screwed solid to the body to get a straight sliding space. We take an ordinary phaeton. We must have a certain space for the windows to slide in a straight line. If one started to design a body, it could be arranged to have the line straight and do away with the rail. When the glass frames are in the rear quarter position one cannot see the individual windows because the glass appears to be one window; this is, when all glass frames are pushed back, making an open car. There are other ways of accomplishing this, such as sliding on rods. I saw a design at the automobile show, by a Mr. Leach. He has only a one-quarter sliding glass frame and cannot go to the other quarter because he uses a curtain on a roller, fastened above the door. It is as tight as a sedan and he claims that it does not rattle.

Mr. Kerr:—What is the approximate cost?

Mr. Steinbeck: — Individually, about $650, starting from the beginning. For instance, if one had an order for 200 or 300 touring cars to be built from the beginning, the tops probably could be manufactured for about $250, or less. On a single order one would find that all phaetons are not alike. Some have sides longer than others and some have more bevel; that is, one cannot fit

this top to one body, take it off and fit it to any other body. It must be made right and fitted to whatever body is under consideration. Each top must be laid out specially and be custom-built.

R. A. LA BARRE:—What advantage is claimed for a top of this kind over a regular sedan if it is built from the beginning?

MR. STEINBECK:—One has a regular phaeton with unobstructed view, and also a closed car, which meets the climatic changes of California and other places where it is warm during the day and chilly at night.

MR. LA BARRE:—It seems to me that construction of that kind, building from the body up, would be as expensive as a sedan body.

MR. STEINBECK:—No, not quite, as less and cheaper material is used. These tops are generally lined with slip-lining material, the labor cost is less and they can be manufactured in quantity for less than the sedan.

PHOTOGRAPHIC RECORDING OF ENGINE DATA

(*Concluded from page* 356)

more important than sensitivity. It is easier to limit oneself to periodic vibrations heavily damped and to obtain extra sensitivity from some other source. One can get all the sensitivity one desires; the main thing is to watch the damping effect.

DR. RICHARD H. CUNNINGHAM:—Will Professor Trowbridge explain the air damping that apparently is used in this instrument?

PROFESSOR TROWBRIDGE:—It is electro-magnetic. The air damping can be disregarded in this instance, as it is very small.

DOCTOR CUNNINGHAM:—I have been using the string galvanometer for many years in the investigation of various phenomena. I have used many of these short metallic strings, but have found that it is utterly impossible to use them where one must depend upon air damping. I was unable to get proper damping except by using short-period quartz fibers. Since about 1905 I have thought that we could use this apparatus in various forms to great advantage for the investigation of many of the phenomena occurring in the automotive industry.

Another instrument particularly applicable to electrical or ignition problems is the string electrometer. It can be made rather sensitive for very high periodic vibrations and will indicate faithfully many of the variations in vibration that we encounter. I first tried to use metallic strings in that apparatus, but really was unable to accomplish anything until I used very small quartz fibers, 1.0 to 1.5 microms (0.00003937 to 0.00005905 in.) in diameter, which possess practically no weight at all. In fact, they behave very peculiarly. If one is held by the fingers and released it usually goes up in the air instead of to the ground, just contrary to what one would expect. One of the points not brought out by Professor Trowbridge relates to the control curves obtained with these metallic strings and the use of proper resistance to get a definite electro-magnetic damping. What is the resistance of the circuit?

PROFESSOR TROWBRIDGE:—It is utterly out of the question to use quartz-fiber strings and that sort of thing for a practical working instrument. The history of this particular instrument is that, for Army use, I had to have something absolutely and completely foolproof and would work 24 hr. per day in the hands of men in dugouts and the ruined houses in France. At that time I did not need a highly damped and well-behaved instrument; since then I have taken up this question of damping and now the instrument is perfectly damped. It can be damped by shortening the string so that, if it moves, heavy currents will flow in the string; that is, it acts like a dynamo and, when buzzing, it drives the current around and therefore checks itself. One must use a low external resistance and adjust it until the system is practically periodic. Fortunately it has so much sensitivity for purposes of this sort that one can afford to throw away 90 per cent of the sensitivity to secure the complete impartiality of its motion; that is, it has no properties of its own whatsoever, not the slightest. Whatever is recorded is due to something that has been impressed upon it. I have a record of an oscillating circuit obtained by breaking an inductive circuit, and its form is exactly what the theory demands.

THE COTTON INDUSTRY

FROM 1870 to 1910 the general trend of world cotton production and consumption was very steady, manifesting a tendency to increase progressively. During this period the per capita consumption of cotton the world over increased about three and one-half times. During the decade beginning with 1910 fluctuations of the most violent sort became common. During the past 10 years variations of from 2,000,000 to 4,000,000 bales occurred on five different occasions.

On the basis of the world's consumption of cotton in the past, it would seem fairly reasonable to assume that consumption for the next few years should be in the neighborhood of 19,000,000 bales. With the exceptionally large stocks eliminated and the prospect of a fairly steady demand, there apparently exists no fundamental factor that should bring about any violent fluctuation in the price of cotton in the near future other than those resulting from crop conditions. The world's population has undergone no material change in recent years, and new uses for cotton are continually being found. It should be fairly safe to predict that as conditions the world over improve economically and politically the dominant influence affecting cotton should be that of a steady increase in the demand for the staple both at home and abroad.

Exports from the United States should be considered from the standpoint of both volume and value, although it is found that there is a practically fixed proportion of the country's crop exported over five-year periods. This proportion is placed at 66 per cent of the crops.

It would seem that cotton is in a stronger position fundamentally than it has been in some time, and that as a consequence its price should be fairly stable in the near future. The above conclusion is based upon the assumption that there will be no material change one way or the other in the production of cotton from the volume and tendency that were manifest in prewar years. Any arbitrary change in the acreage planted would, of course, be a factor that would have to be given due consideration.—W. F. Gephart, vice-president and director of industrial service department, First National Bank in St. Louis.

Discussion of Papers at the Annual Meeting

THE discussion of the papers presented at the recent Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum amount of effort.

In addition to discussion given below the discussion of Economics of Motor Transport, by M. C. Horine; Recent Research Work on Internal-Combustion Engines, by Harry R. Ricardo; The California Top, by P. W. Steinbeck; and Photographic Recording of Engine Data, by Prof. Augustus Trowbridge, is printed elsewhere in this issue of THE JOURNAL, following the individual papers, The discussion following the presentation of the paper by Prof. R. E. Wilson and D. P. Barnard, 4th, entitled the Mechanism of Lubrication, will, it is expected, appear in an early issue of THE JOURNAL, together with the paper.

VISCOSITY AND FRICTION

BY WINSLOW H. HERSCHEL

THE author divides the study of lubrication into different regimes in which different properties of the lubricant have the controlling influence and discusses at length viscosity effect in the complete-film-lubrication regime, including comment on the properties of lubricants, units for viscosity measurement, absolute viscosity relation to the readings of instruments ordinarily used and mathematical analysis, with reference to data that are presented in tabular and chart form.

Viscosity estimation at one temperature from the observed viscosity at another temperature is then treated in a somewhat similar manner, inclusive of discussion bearing on complete film lubrication, as are the subjects of journal friction and viscosity in which the mathematical analysis is continued, and friction tests are described briefly, copious specific references being given.

Consideration is given to the transition point, the relation between the different factors at the transition point and incomplete film lubrication and the oiliness of lubricating oils, the last including a description of Bureau of Standards tests.

A lengthy discussion of the differences in oiliness of different lubricants shown by laboratory and service tests follows, many references to tests and testing machines being cited and quotations made from reports.

Ten specific desirable features of oil-friction testing-machines are enumerated and commented upon in the light of previous experiences that are cited, and nine specific conclusions regarding viscosity and friction are stated.—[Printed in the January, 1922, issue of THE JOURNAL.]

THE DISCUSSION

H. S. MCDEWELL:—In connection with the maximum temperature at which the viscosity is desirable and in regard to some of my own work, I had occasion to determine approximately the temperature of the oil-film existing in an Hispano-Suiza Model-I aeronautical engine. The cylinder construction of that engine is such that the heat is transmitted through two metals, a steel cylinder and the aluminum body into which the steel liner is screwed. No matter how carefully the machine work may be done, there is an infinitesimal gap between the two metals. Consequently, the temperature existing inside the cylinder, for a given cooling-medium or jacket-water temperature, is greater than in an engine in which the construction is such that the heat must be transmitted through only one metal. In the comparative test of two oils of the same base but of material difference in viscosity, the oil consumptions were compared by a cut-and-try process on the basis of the viscosity existing at an assumed oil-film temperature. On that basis it was found that the oil consumptions were exactly proportional to the respective fluidities at 210 deg. fahr., which are the inverse of the viscosities, thus giving a probable temperature of oil-film in the neighborhood of 210 deg. fahr. for a Model-I Hispano-Suiza engine. In an engine of conventional cylinder construction using only one metal the oil-film temperature is probably below this figure; consequently, Dr. Herschel's remark in regard to the inadvisability of the determination at 350 deg. fahr. is substantiated. The reason that the temperature mentioned is so low probably is that in heat transmission there is always a dead-gas film between the source of heat and the metal. In this film the temperature drop is very great. The dead-gas film in this case exists outside the oil-film and consequently serves to protect it. There is no question that, if the oil-film were subjected to the temperatures actually existing during combustion, there would be no oil left on the cylinder walls. It would certainly be burned up.

T. E. COLEMAN:—Is there a connection between viscosity and friction, and the clearance of a piston or a bearing? That might come in with reference to oiliness, I imagine. I have in mind particularly a car guaranteed to run 15,000 miles without oil-pumping. The salesmen inform me that the aluminum piston used has less than 0.002 in. clearance when cold and that means of compensating for the expansion is provided. That piston must expand somewhat and I think there must be some connection between the kind of oil used and the thickness of the oil-film.

DR. W. H. HERSCHEL: — According to the ordinary theory or definition of viscosity, the resistance is inversely proportional to the thickness of the oil-film; that

is, the narrower the clearance, the greater the friction. Therefore, by reducing the clearance to a very small value, one would increase the friction, in complete film lubrication; but, in all probability, there is seldom if ever complete film lubrication in the cylinders. It exists generally in a journal bearing in which forced-feed lubrication is employed, but in cylinder lubrication, in which oiliness rather than viscosity is the predominant factor, it is very difficult to answer the question accurately because there is a condition of incomplete film lubrication in the cylinder. We are subjected to laws of lubrication that include this factor of oiliness, which is rather vague and indefinite, and we cannot say with certainty just what the effect of the variation of clearance would be.

DR. GEORGE W. COGGESHALL:—What is Dr. Herschel's opinion as to what constitutes oiliness?

DR. HERSCHEL:—Possibly to a chemist this paragraph from a review of a paper by W. B. Hardy will throw some light on the subject.[1]

> The relation between lubricating power and chemical constitution was investigated by measuring the force required to move a slider of bismuth over a surface of the metal. The static friction in a simple chemical series, such as the fatty acids, the alcohols and the paraffins, decreases with the molecular weight but not in a simple manner, the chemical constitution playing an important part. At the point in the series where the lubricant becomes a solid at the temperature of observation, there is no break. The more saturated cylic compounds are better lubricants than the less saturated cylic compounds, but no ring compound is a good lubricant. As lubricants esters are inferior to their related free acids and alcohols, but to this rule the ring esters are exceptions. The hydroxy acids have remarkable lubricating power, but the ring compounds are again exceptional.

Oiliness, as I defined it, is the factor or factors due to chemical composition or anything else that will cause a difference in friction when two lubricants are used in the same machine under identical circumstances. For example, with a cutting oil one has very high concentrated pressure within a small area.[2] This brings out the effect of oiliness. Everyone knows that a lard oil is a good cutting oil. If a mineral oil of the same viscosity as lard oil is used, one gets a comparison of the effect of oiliness because, both being of the same viscosity, the effect of viscosity is excluded, although I will admit that there is a slight influence from the change of viscosity with the temperature. We know very little about the temperatures of the oil-film in cutting metal. We have tried cutting off discs from a steel bar with different oils. The tool was fed mechanically so that the conditions of use were constant. With one oil we have perfectly smooth discs that look as if they had been polished; with another oil we have jagged surfaces. That difference, so far as I can make out, is due to the difference in oiliness.

DR. COGGESHALL:—Is there some chemical difference?

DR. HERSCHEL:—The difference is perhaps in that intermediate region in which it is difficult to determine whether it is chemical or physical. Probably it is due to what is called adsorption or adhesion. It is the inter-facial tension between the metal and the lubricant. It is the force with which the lubricant adheres.

DR. COGGESHALL: — Would the quality of the metal have an effect?

DR. HERSCHEL:—The quality of the metal certainly does have an effect. There is an enormous difference in friction when one uses the same lubricant on different metals. In other words, if there is an inter-action between a lubricant and a metal, this inter-action will be affected both by the quality of the metal and by the quality of the lubricant; it is this inter-action between the two that makes the oil-film adhere to the metal and determine the coefficient of friction.

J. W. STACK:—Has Dr. Herschel made experiments in a comparative way between the mineral and the fatty oils as to surface tension or liquid to solid angle?

DR. HERSCHEL:—Surface tension is best explained in the work of Wells and Southcombe.[3] They find that surface tension as given in the ordinary tables has no effect, because the surface tension of all oils is practically the same; but, on the other hand, if one measures what is called inter-facial tension by the size of a drop forming under water, a method developed by Donnan but used by Wells and Southcombe, one will find great differences between oils. It is this inter-facial tension, and not surface tension, correctly speaking, that makes the difference or at least is an indication of the difference in oiliness.

We are now investigating the effect of variation in the organic acidity of mineral oils due to causes one cannot explain but not due to compounding with fatty oils. We are trying to determine the effect of changes in this organic acidity due to petroleum acids, on inter-facial tension and, hence, upon oiliness and the coefficient of friction.

R. W. A. BREWER:—The author refers to oil-films "of the order of 0.000125 in." It seems to me that the errors in smoothness of surface due to its mechanical formation are so very great in comparison with these very small dimensions that it is almost futile to talk commercially of oil-films of that thickness.

DR. HERSCHEL: — The information concerning the thickness of oil-films is very meager. Very little work has been done on the subject. In very few cases has the film thickness been measured and yet, as the film thickness is one of the factors that comes into all equations for determining the turning moment or coefficient of friction or the relation between viscosity and friction, it cannot be neglected. One cannot check the equation for determining the relation between viscosity and the coefficient of friction unless one knows the film thickness.

MR. BREWER:—Do not those film thicknesses come into play at very much larger dimensions than these that are given? The point I raise is that the film dimensions are so very minute. They are much smaller than one meets in the ordinary practice of lubrication.

DR. HERSCHEL:—Possibly Mr. Brewer has overlooked the fact that the thickness of oil-film that he cited was in gear lubrication, and that in journal bearings the journal is not concentric in the bearing except at very high speeds. At very high speeds it approaches the concentric condition, but at moderate speeds the journal is eccentric, and therefore the film thickness at its thinnest place is less than one-half the difference between the radii of the journal and the bearing. With metallic contact, as in the case of rest, it is obvious that there will be practically no film thickness at all, or at least nothing but a film thickness due to the adsorbed film. Therefore, one does meet in practice, and certainly when approaching the state of rest, film thicknesses that are as small or smaller than the values I gave.

MR. BREWER:—These are only local thicknesses, I take it, at the highest spots of the two surfaces.

DR. HERSCHEL:—They are at the point of nearest ap-

[1] See *Chemical Abstracts*, vol. 15, p. 3159; for original see *Proceedings of the Royal Institute of Great Britain*, Feb. 27, 1920.

[2] See Bureau of Standards Technologic Paper No. 204.

[3] See *Journal of the Society of Chemical Industry*, vol. 39, p. 51T.

proach. The condition is not due to the irregularities in the surface, but to the fact that the journal is eccentric in the bearing.

MR. BREWER:—Are the thicknesses of oil-film measured from the parts of the metal that are in closest contact?

DR. HERSCHEL:—Yes, at the point of nearest approach.

NEIL MACCOULL:—Professor Kingsbury made some interesting experiments several years ago to determine what constitutes "oiliness." When I asked him whether he found much difference between oils as far as oiliness is concerned, he asked me the pertinent question, "What is oiliness?" Mr. Deeley has developed a machine in England for measuring oiliness; it is apparently a machine for measuring the static coefficient of friction. However, that is not the whole story because, when the machine is very heavily loaded, all kinds of disturbance are evident with an ordinary mineral oil; but with a fatty oil the machine runs much more smoothly. Prof. R. C. Carpenter, of Cornell University, made experiments many years ago in which he tried to measure the wear of different bearing-metal alloys. His machine was devised so that he was able to measure an appreciable amount of wear after a few hours of running. The interesting fact was demonstrated by him that when a series of alloys having different percentages of antimony and lead was investigated, the minimum wear was with lead, which gave the maximum friction, and the alloy showing the minimum coefficient of friction showed the maximum wear. Can we expect that, if one oil is more oily than another, the wear that develops in a bearing will be less with the oil that is most oily? It may be that the matter of wear does not vary in the same direction as does friction.

CHAIRMAN H. C. MOUGEY:—Is there any difference in the oiliness of mineral oils, or is it necessary to add a second oil to the mineral oil to obtain this property of oiliness?

DR. HERSCHEL:—In considering what Mr. MacCoull has said, one should refer to the portion of my paper on the friction testing of bearing metals. Primarily I am not a metallurgist; I am an oil specialist and have not emphasized this subject of testing bearing metals because I am interested in lubricants. In my paper concerning the testing of bearing metals I have quoted Goodman's opinion, that all wear in friction tests is due to the imperfect fitting of the bearing and the journal. Therefore, I think we must accept with caution any conclusions reached in regard to the comparative amount of wear. If Goodman is correct, the wear observed is merely an indication of variation in fit between the bearing and the journal, and not an indication of anything else.

Chairman Mougey's question regarding the necessity for adding fatty oils to improve the oiliness opens up a most interesting subject; that is, whether organic acidity due to a petroleum acid in the oil, and not to compounding, is beneficial in the same way as the organic acidity due to the compounding or addition of fatty oils. The subject is under investigation. There is also the question whether, by an addition of graphite in the colloidal form so that it will not settle out, we may obtain the same advantage in reducing the coefficient of friction that is gained by the addition of a small percentage of fatty acid, as found by Wells and Southcombe.

CHAIRMAN MOUGEY:—If I understand correctly, there would be no difference in the oiliness of mineral oils except for the presence of foreign matter, possibly a petroleum acid of some kind, that is present in one mineral oil and not in another. Does that mean that the more highly refined oils would be inferior as lubricants because these desirable qualities have been removed during the process of refining?

DR. HERSCHEL:—It depends entirely upon what is meant by the term "foreign matter." Until we know the source of the acid in the test for organic acidity of a pure uncompounded mineral oil, we shall not know whether to classify oils of perceptible organic acidity as containing foreign matter.

There are several possibilities as to the sources of petroleum acids in oils. They may be in the original crude; they may be a result, let us say, of cracking in the distillation; they may be a result of treatment with sulphuric acid. If there are certain hydrocarbons in the oil as a result of any of these processes of refining, it is a matter of very exact definition to determine whether these recently formed hydrocarbons should be called "foreign matter." They perhaps are not present in the original petroleum, but possibly are oxidation products of the hydrocarbons in it. Do they or do they not constitute "foreign matter?" We do not know as yet whether these petroleum acids are an advantage or a disadvantage.

There may be such a thing as over-refining and removing too great an amount of these acids. From that viewpoint it is just as bad to over-refine an oil as not to refine it enough. We lack methods of testing to indicate when an oil is refined enough and when it is refined too much. We need a method of testing to indicate when an oil has been sufficiently refined. It seems probable that it is a matter of compromise. Apparently, we want enough of these unsaturated products in an oil to give good oiliness. If we have too many unsaturated compounds in the oil, it will have a tendency to gum. The new school of thought seems to indicate that to give good lubrication we should have an oil that will gum. Quoting from R. M. Deeley:[4]

> It appears then that the true lubricant is an unsaturated compound possessing all the attributes of such a compound; that is, (*a*) capacity to absorb iodin, bromin, oxygen and so on; (*b*) solubility in strong sulphuric acid; and (*c*) a higher carbon-hydrogen ratio than the saturated derivative.

That sounds very much as if the author were defining a drying oil. According to that definition we would expect linseed oil to be the best substance for a lubricant, but common sense tells us this is not true. Therefore, if there is any truth in this, we must say that it is a matter of compromise between enough of the unsaturated compound to give good lubrication and not enough to cause gumming.

DR. COGGESHALL:—It is known to be true, I believe, that the addition of fatty or organic acids to mineral oil will increase the oiliness. Have those increases always been determined on bearing metals subject to attack by an organic acid? There are a few metals that are not attackable by organic acids. Have any experiments been made using those metals as journal bearings and as shafts? If a platinum journal were used, we could assume, I think, that there could be no chemical action between the platinum and the organic acids. We do know that organic acids will attack iron and other ferrous metals. If the addition of organic acids to mineral oils did not increase the oiliness on a platinum journal, we could pretty nearly conclude that there was no chemical combination between the fatty acids and the journal. If the addition of organic acids did increase the oiliness,

[4] See *Proceedings of the Physical Society of London*, vol. 32, p. 4S.

we would be forced to conclude that there was some chemical change in the lubricant, rather than a combination with the metal of the journal. There might be adsorption on platinum metals just as on ferrous metals.

DR. HERSCHEL:—It seems to be a question whether to include adsorption with chemical or with physical action. This I will not undertake to decide. I think it is safe to leave it that way: a case of adsorption. The report of the Lubricants and Lubrication Inquiry Committee explains the work done in England. This committee not only obtained the results directly by friction tests but has used the inter-facial-tension apparatus. There is a slight hiatus in the line of argument, because it is impossible to detect directly the attraction, inter-facial action, the adsorption or whatever one wishes to call it, between a lubricant and a bearing metal. It must be determined by indirect means, by the inter-facial action between a lubricant and water, but the conclusions derived from the observation of drops of oil forming under water have been substantiated by tests made on friction-testing machines.

B. F. TILLSON:—As I understood him, Dr. Herschel referred to the saturated hydrocarbons as being the lubricating bodies and later spoke of the unsaturated hydrocarbons as contributing the lubricating qualities to an oil. This confuses me.

DR. HERSCHEL:—It should be "unsaturated hydrocarbons," according to the modern theory. These are supposed to be the valuable constituents of the oil as far as lubrication is concerned.

MR. TILLSON:—That is what I have heard from other sources. In that respect it is of interest to note some tests made of oils distilled from oil-bearing shales. Some of these oils show very light viscosities and low densities. Their lubricating qualities under test conditions thus far have seemed to be superior to those of the average internal-combustion-engine lubricant. When tested in passenger cars and trucks, greater mileage per pint of oil consumption was shown, with an apparently greater engine horsepower in the same engine. These oils are from a petroleum-base shale-oil. In the process of distillation, possibly due to cracking in the retorting of the shale, they probably contain a large percentage of complex unsaturated hydrocarbons.

RELATION BETWEEN FLUID FRICTION AND TRANSMISSION EFFICIENCY

BY NEIL MACCOULL

THAT all of the variable factors of automobile friction-losses such as the quantity and viscosity of lubricants, the efficiency of worm-gearing and part-load modifications are not appreciated, is indicated by an examination of the literature on this subject which reveals a lack of necessary data. Experiments to determine the mechanical losses, including all friction losses between the working gases in the engine and the driving-wheels of the vehicle, are described and supplementary data are included from Professor Lockwood's experiments at Yale.

Three distinct possibilities for increasing the fuel economy of a motor vehicle are specified and enlarged upon, gearset experiments to secure and develop data for a four-speed gearset being then described and commented upon at length; photographs and charts illustrative of the equipment used and the resultant data are included. The effects of varying the speed under no-load and load conditions are studied, inclusive of mathematical analysis, and the efficiency of the gearset and noise measurements made in regard to it are discussed. The paper is then summarized. [Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

R. W. A. BREWER:—The Hopkinson method of carrying out a test of this sort is interesting. Some 30 years ago Dr. Hopkinson developed a system of testing alternating-current generators that has been modified in this particular test. It seems to me that this method is adaptable to any kind of rotary machine and should be adopted very much more widely. I am very glad to see that it was used in this case, and also that results were obtained which can be relied upon.

Fig. 1 of the paper refers to the mechanical losses and to wind resistance and tire losses. Mr. MacCoull thinks that not much work or investigation has been done along these lines. But much has been done. Between 1909 and 1914 I was doing considerable automobile racing on the Brooklands track. In the course of the work it was necessary to design cars to give a guaranteed performance. To do so wind and other resistances had to be considered, because these resistances are the principal factors in the whole design. To determine the accuracy of the design some tests were made on a single-seat racing-body, placing an ordinary number-plate on the front of this body, and subsequently a four-seat automobile, a sporting model, was designed having a difference of resistance under test conditions exactly equal to the resistance of that number-plate. Tests of this kind show that designs for practically any predetermined wind-resistance can be made. Tests of that particular body show that one can make automobile-body forms to give an extremely low resistance if the proper method is used.

Mention was made of variations in resistance in a gearbox with varying quantities of oil. It is an old racing trick to put practically no oil in the transmission; such oil as does go in is, as a rule, engine oil. That makes a considerable difference in the friction loss.

Two points of resistance are very important in an automobile. One is the propeller-shaft loss, which varies with the design of the propeller-shaft and of the universal-joints. The other loss is due to faulty springing and to wheel-spinning. It is obvious that wheel-spin is a very prolific source of lost energy in the propulsion of a car.

PROF. E. H. LOCKWOOD:—A novel experiment on the measurement of wind resistance of vehicles is now being carried out at the Kansas State Agricultural College, Manhattan, Kan. The general plan is to expose the vehicle in a suitable location to the sweep of the Kansas winds, which are said to be both intense and steady at times. The test vehicle is placed on a circular turntable floating on water in a concrete reservoir. In this way the vehicle can be oriented to face the wind, the direction and velocity of which are indicated by the usual instruments. The total force of the wind exerted on the vehicle is measured by the dynamometer pull on the frictionless

floating turntable. Interesting and valuable results may be expected from this equipment.

Mr. MacCoull's experiments showing a marked increase of gearbox friction at low temperatures have been confirmed by dynamometer tests at the Mason Laboratory, Yale University. In the latter experiments the procedure was modified by chilling the entire transmission to about 32 deg. fahr. by allowing the car to stand overnight in the open air. The entire chassis friction, both front and rear, was measured in the cold state, and at intervals of 30 min. thereafter. The gears and transmission were run under load to warm-up the lubricant, until the latter reached a temperature of about 130 deg. fahr. Two typical examples are given to show the extent of friction variation produced in this way.

Quartermaster Standard Class-B truck No. 432,799 had run 3600 miles at the time of test and was in excellent condition. The empty truck weighed 11,540 lb., of which 6875 lb. was on the rear wheels. Rolling-resistance measurements were made with gearbox temperatures at 32 deg. fahr., these finally reaching about 130 deg. fahr. The cold test showed, for the front wheels, 80 lb.; for the rear wheels and the transmission, 166 lb.; or a total of 246 lb. The hot test showed 80 lb. for the front wheels; 130 lb. for the rear wheels and the transmission; or a total of 210 lb. The increase in the total rolling resistance due to chilling the lubricant was about 17 per cent.

A similar test was run with a duplicate Class-B truck, that had run only 300 miles, in which the engine and the transmission gave evidence of excessive internal friction. The rolling resistance of this truck was considerably greater. The cold test showed, for the front wheels, 83 lb.; for the rear wheels and the transmission, 295 lb.; or a total of 378 lb. The hot test showed 83 lb. for the front wheels; 190 lb. for the rear wheels and the transmission; or a total of 273 lb. The increase in the rolling resistance due to chilling the lubricant was 39 per cent. Intermediate measurements showed that the decrease in the friction was rapid as the lubricant warmed-up, but slow from temperatures of from 80 to 130 deg. fahr.

A MEMBER:—In Fig. 6 of the paper, do any of the curves shown refer to greases? Were the two transmission units that were put together statically balanced? If not, the ratings taken need to be corrected considerably.

NEIL MACCOULL:—In Fig. 6 the cross-arm is over the gearboxes, with the spring-scale by which we measured torque losses on the left-hand side. At the right-hand side of the gearboxes large iron weights are shown suspended from the end; these were installed to balance the gearboxes. All our readings were corrected by about 1½ lb. to compensate for the lack of balance.

In regard to the use of greases I place little reliance on the results I have given, because it is so difficult to measure their temperatures. We have no assurance whatever that the temperature of the grease where the thermometer is inserted is the same as the temperature of the grease around the gears. However, the curve for oil No. 3, as it is called in Fig. 9, is a grease that was tried, but I question that also to some extent because, as shown in the cross-section of the gearboxes in Fig. 4, there is a little pocket at the left-hand end of the gearbox where the engine shaft goes through between two of the roller bearings. It is very clear that after operating for some time this space would be filled with the lubricants used. The tests we made were of too short duration to make certain that the grease got up in there; so, it may be that the losses would be higher after a long test. Oil No. 7 was a light mineral oil in which there was a small percentage of grease, but not enough to prevent it from being fluid. I complained about the difficulty of cleaning out a grease, having in mind a particular grease that would not flow of itself. It can be removed only by digging it out, since it is not soluble enough in kerosene or similar liquids to wash out easily.

H. C. DRAKE:—In his work on transmissions did Mr. MacCoull make any tests to determine the losses with the gears in neutral?

NEIL MACCOULL:—No, because one would get only the readings from one gearbox. The same thing is true with a gearbox on an idler. That would be interesting, of course; our experiments were very incomplete.

H. C. DICKINSON:—In discussing this very interesting and valuable paper I should like to call attention to one point that the author seems to have overlooked, and that may be of considerable importance. In using the two gearboxes mounted in a cradle so that the resultant torque on them alone can be measured, Mr. MacCoull adopted a method that is in accord with good experimental procedure; that is, he has succeeded in measuring directly the quantity that he wishes to measure instead of deducing the result as the difference between the power input and the power output. The latter method has the inherent disadvantage that both measurements must be made with extreme accuracy to give any reasonable accuracy to their difference.

But, in adopting this method, the apparent torque on the gearbox yoke system is dependent on its center of gravity. The grease or oil in the gearboxes is a part of the system and any displacement of it can change the position of the center of gravity and thus change the balance of the system; or, in other words, the measured torque independently of the actual torque applied. When the gears rotate, they displace the oil in the gearcase and change the center of gravity by an amount depending upon the shape of the gearcase, the viscosity of the oil, the depth of oil, the speed and direction of rotation and perhaps other things. Moreover, the system as used is not symmetrical as regards displacement of the oil; hence, there is no assurance that the displacement in one of the gearcases will balance that in the other. As a matter of fact, they will both tend to change in the same direction.

The magnitude of these corrections for a Class-B-truck transmission has been determined incidentally by S. von Ammon, of the Bureau of Standards, in connection with a study of efficiencies in rear-axle construction for the Quartermaster Corps. With this gearset, the horizontal displacement of the center of gravity necessitates corrections which are of the same order of magnitude as some of the total net torques measured by the author. While these errors may be much less in the gearcases he has used, it is hardly safe to neglect them without a careful determination of their magnitude. For instance, it is possible that the constant K, which the author states depends upon viscosity and oil level, is in reality not a characteristic of the gear and bearing friction at all, but a measure of the displacement of the center of gravity of the oil. At any rate it has the same general characteristics as the error introduced by displacement of the oil.

MR. MACCOULL:—The possible error due to the changing of the center of gravity when the gears displace oil is very difficult to calculate. Observations of the effect of gear rotation on the displacement of the oil show that the oil usually builds up around the upper shaft as a

symmetrical mass having about the same center of gravity as the shaft. The oil thus picked up and carried by the gears has the effect of lowering the level of the remaining oil, but no observations were made to determine the extent of this. There is little lateral change in the center of gravity. It does not seem possible that the variation in the height of the center of gravity could be as great as that caused by changing the quantity of oil present from 4 to 8 qt., which would introduce an error slightly in excess of 3 per cent. To eliminate this source of possible error, further tests will be made on the effect of changing the quantity of oil.

CONTINUOUS DIE ROLLING

BY G. R. NORTON

THE process of continuous die rolling and the products possible with this method of manufacture are described and illustrated. The improvements that have been made were the result of efforts to produce more complicated sections by this process, with greater accuracy, and these are discussed at some length.

The physical characteristics of steel that must be considered are commented upon and forming that is effected in one pass is described, consideration being given the requirements of rolled forging blanks.

The cost of operation is treated and the equipment used is discussed, showing how this process differs from other methods of making the same things, as to both the operations necessary and the character of the product. [Printed in the January, 1922, issue of THE JOURNAL.]

THE DISCUSSION

G. R. NORTON:—To make the process perfectly clear, I wish to point out wherein it differs from the other rolling processes that are somewhat similar. This consists of the manner of forming the variable-section bars which is done entirely in the final pass after the bar has been reduced from a billet through an ordinary roll train. This final forming operation can be made in the last stand of a set of rolls, or in a separate finishing stand, the latter being a little more flexible and having a better arrangement. The only articles that have ever been made commercially in this way are clip-sections, wagon-box straps and some things of that character. They have been produced for many years by the Carnegie Steel and other companies but usually take the form of round sections alternating with flats, half-rounds or half-ovals, and no attempt is made to put impressions in the pair of rolls; one roll carries an impression while the other is perfectly flat. In the process described in my paper we match the impressions in the rolls by using a set of gears opposite the driven end of the rolls. We can match the rolls exactly by a method of adjustment, roll symmetrical sections, make offsets and perform similar operations. The improvements have been entirely along these lines. There is nothing particularly novel about the idea; in fact, it was advanced in 1835. Except for the cases mentioned, I think very little, if anything, has been put on the market because of the difficulties of production. One limiting factor is the amount of reduction that can be obtained without producing a flash or over-fill on the bar. In the ordinary rolling process the over-fill cannot be taken care of, but in many pieces we regard that exactly the same as the forging flash produced in the drop forging.

J. H. NELSON:—The process is exceedingly interesting and, if carried far enough, would, I think, be exceedingly useful as a preliminary to drop forging. Just what can be done in regard to it depends upon whether it can be made to pay. That is the great problem, just as it is a problem now in forging automobile parts. It is necessary, as was stated, to forge down to distribute the material to the proper places. If sections could be made of the proper shapes, it would save much time in the forge shop and increase production. The effect, however, would be to require a stock of a particular size and character for each job. In other words, it would not be possible to stock up a yard with a supply of steel. It thus might work a hardship on the customer, particularly during times when only small orders are placed. On certain classes of orders requiring one exceptionally large number of either identical or very similar forgings such a procedure might work out very satisfactorily.

CHAIRMAN F. P. GILLIGAN:—What is the etching substance used on those sections?

MR. NORTON:—I think it is iodin.

METHODS OF MEASURING DETONATION IN ENGINES

BY THOMAS MIDGLEY, JR., AND T. A. BOYD

THE various methods employed to measure detonation or fuel knock in an internal-combustion engine, such as the listening indicator, temperature and bouncing-pin, are discussed and the reasons all but the last cannot be employed to give satisfactory indications of the detonation tendencies of fuels are given. The bouncing-pin method, which is a combination of the indicator developed by the author and the apparatus designed by Dr. H. C. Dickinson at the Bureau of Standards, is illustrated and described. In this method the evolution of gas from an electrolytic cell containing sulphuric acid and distilled water measures the bouncing-pin fluctuations in a given period of time. The accuracy of this method of comparison is brought out in a table.

The qualities that a standard fuel must possess are explained and the objections to a special gasoline are pointed out. The use of a combination of a non-detonating and a detonating fuel as the standard is developed and the reasons that led to the use of hexane with diethyl selenide and isopropyl nitrite for a fuel standard are mentioned. [Printed in the January, 1922, issue of THE JOURNAL.]

THE DISCUSSION

A. C. BOCKMANN:—In the matter of a standard of comparison for apparatus for measuring detonation, I gather that there would be some variation. How is that determined?

T. A. BOYD:—A standard fuel, the characteristics of which are known, is always used as a basis of compari-

son, on account of the condition to which Mr. Bockmann refers. By running the standard fuel at the same time and under the same conditions as the fuel under examination, the variables introduced by changing engine conditions and necessarily always present are ironed out.

THOMAS MIDGLEY, JR.:—The method adopted is that of measuring the fuel, not the engine. When applying the measurement to the engine, we can compare any engine with any other. By this method we can determine very accurately a blend of the standard fuels that would just verge on detonation in a given engine. Let us assume that it has a 40 to 60 value. We can then take the same mixtures to another engine and determine the value for that engine, obtaining, say, a 50 to 50 value. These terms would then express the measurements of the engines. Thus, measuring the engine gives us practically the same results concerning detonation as measuring the difference in fuel oils.

CHAIRMAN A. L. NELSON:—My understanding is that with two standard fuels we determine two points, an upper and a lower point after detonation. Are the intermediate points on a straight line?

MR. BOYD:—They very seldom lie exactly in a straight line, but usually in a smooth curve. As many concentrations of the standard with which comparison is being made can be employed as is necessary or advisable. A smooth curve, which never has a great deal of curvative, can then be drawn through these points; or, if a high degree of accuracy is desired, such concentrations of the standard may be used as lie so close to the fuel under examination in detonating characteristics that the points can be joined by a straight line without introducing any measurable error. Thus, for example, in the cases reported in the paper, in which the operator was endeavoring to determine the composition of unknown blends of kerosene and gasoline, he proceeded as follows: From the stock of the same ingredients he prepared by trial two blends, one of which had a very slightly greater detonating tendency than the fuel under examination, as measured by the amount of gas evolved, and one of which had a slightly less tendency to detonate. A number of runs were then made with each of the fuels, checking them against one another and averaging the results. The averages thus obtained from each of the fuels of known composition were plotted on a chart having the amount of gas evolved and the relative kerosene-gasoline composition as its vertical and horizontal axes, respectively, and the two points were joined by a straight line. Projecting down from the point at which this line crossed the horizontal line corresponding to the volume of gas evolved by the fuel under examination then gave its composition directly, and with a surprising degree of accuracy.

A MEMBER:—We have here a definite addition to the methods of ascertaining the nature of detonation. There have been many misgivings as to just what detonation is. Any means that will help determine the line of demarkation between detonation and highly intensive burning is of value. Perhaps some portions of Mr. Ricardo's paper concerned a near approach to detonation that was not detonation. It may be that after more work shall have been done upon the subject we shall be placed in possession of an instrument that will be capable of telling us exactly what occurs, and we shall be able to find some line of demarkation where detonation stops and highly intensive burning begins.

PERTINENT FACTS CONCERNING MALLEABLE-IRON CASTINGS

BY ENRIQUE TOUCEDA

ADDRESSING the structural engineer and the purchasing agent particularly, the author discusses the relationship between them and the foundryman with regard to malleable-iron castings and enumerates foundry difficulties. The characteristics necessitating adequate gating for such castings are described and illustrated, inclusive of considerations regarding pattern design, followed by a statement of the considerations that should influence the purchasing agent when dealing with foundrymen.

Possible casting defects are described, illustrated and discussed, comment being made upon casting shrinkage and machinability. Improvements in annealing-oven construction and operation are reviewed and the records of 100 consecutive heats in different plants are tabulated. The materials for casting that compete with malleable iron are mentioned and its physical characteristics are considered in some detail.

Emphasis is placed upon the necessity for the elimination of casting shrinkage and a brief summary is made of the most important features of the paper. [Printed in the January, 1922, issue of THE JOURNAL.]

THE DISCUSSION

R. H. SHERRY:—Mr. Touceda should have laid more stress upon the matter of the design of malleable castings. Some very peculiar things appear in the old books on automobile design. For example, one will find the steering-knuckle represented as being machined at right angles, which would cause it to fracture after comparatively short service. Some of the things perpetrated in tools show the same faulty design that often is exhibited in castings. It should be one of the duties of the metallurgist to use his best judgment in examining the designs for malleable castings, before he even undertakes their consideration.

I have in mind one casting that was stated by a prominent automobile engineer to be impossible to make, but by a minor change, I think it was an increase in thickness of about 1/8 in., a considerable sum of money was saved by using that part. I recall also the clutch hub of a certain popular car which is a malleable casting with cyanided splines. A number of them are placed on a steel rod and rotated over the cyanide pot. The malleable iron cyanided very readily and with perfect satisfaction. I believe this form of hub can be made at much less cost than any other.

ENRIQUE TOUCEDA:—The design of malleable-iron castings with sections disproportionate in such a way as to make them almost impossible to be cast free from shrinkage is the one big difficulty that confronts the foundryman. To produce sound castings he is forced to resort to almost every expedient known to the molding art. A complicated casting of disproportionate sections should not be regarded in the light of a single casting having one or perhaps two gates, but as a mass of metal made up of a lot of separate castings united by thinner sections that may be considered as gates joining heavier

parts and actually a part of the casting itself. If two heavy parts are united by one that is too thin, as is the case with many automobile castings, the thin portion will freeze before the others have had their full quota of metal. If the uniting part is thickened slightly, this defect can be overcome.

C. S. SCHROEDER:—With reference to the approximate limiting thickness of a malleable casting, how thick can such a casting be made and still retain the high tensile-strength and elongation that are obtained with ½-in. sections?

MR. TOUCEDA:—In the case of sections having a thickness of 1 in., it is not believed that any consequential variations in strength will be found in any part of the section. In a section 2 in. thick, some difference in strength would be found between a specimen taken close to the surface and one from the center of the section. This might amount to as much as 4000 lb.; but, inasmuch as the average ultimate-strength of malleable cast-iron is 53,000 lb. per sq. in., the strength of the bar cut from the center would still be much higher than the requirements laid down by the American Society for Testing Materials. Being cut from metal all of which is very near to the neutral axis, the loss in strength would be negligible. There is no difficulty in the breaking-up of the hard iron carbides during the annealing, irrespective of the thickness of section, as this conversion is a function of time and temperature and will be complete in all cases, provided the composition is correct from a metallurgical viewpoint.

MR. SCHROEDER:—But is not the outer structure ruined by prolonged annealing?

MR. TOUCEDA:—Not at all. Many believe that the strength of malleable iron lies mainly in the skin, owing to the surface metal being decarbonized, but many tests on machined samples prove that this is not so. It is really a matter of soundness whether duplicate bars, one machined and the other not, will show a difference in strength. One reason for the old belief was that tests were made on bars that lacked soundness due to shrinkage. When the skin was removed by machining, the test was made on that part of the bar that lacked strength because of this defect. The great value of the malleable casting lies not only in its high strength and ductility but in the ease with which it can be machined. There is no other ferrous product that can be machined at such a high rate of speed. Many companies attain a rate of 150 ft. per min.

CHAIRMAN F. P. GILLIGAN:—Do automobile engineers show any lack of response to requests for alterations of design that will affect their products?

MR. TOUCEDA:—There has been an improvement within the last year. Engineers are beginning to realize more fully the reasonableness of such requests. We can certainly produce better results if designs are better.

CHAIRMAN GILLIGAN:—Has there been any trouble with the factory people in that respect?

MR. TOUCEDA:—The trouble is all along the line and not with the manufacturer particularly. In his design the engineer considers mainly what sections he must have to assure sufficient strength in service, in many cases without realization of or regard for the problems that may arise in connection with the production of the castings. I am glad to state that our requests for modifications in the design of patterns are now met in a much more tolerant manner than formerly. In one recent instance a pattern was changed at our request and success immediately followed.

PASSENGER-CAR BRAKES

BY J. EDWARD SCHIPPER

STATING that the problem of deceleration is just as important and necessary of solution as is the one of providing car-acceleration ability, the author gives a comprehensive survey of present braking practice and outlines future requirements and possibilties.

Design factors are considered at length, as well as the subject of what constitutes uniform and effective braking-power, various illustrations and descriptions being included of different types of brake. Brake-actuating means, the calculation of brake-drum size, car-stoppage ability, brake equalizers and brake-linings are commented upon in some detail.

The future of brakes is discussed with reference to the use of the engine as a brake, four-wheel and front-wheel brakes, the servo principle of brake operation and various novel braking methods. A brief summary of what is considered good practice with regard to truck brakes is appended. [Printed in the April, 1922, issue of THE JOURNAL.]

THE DISCUSSION

H. W. SLAUSON:—I was much interested in Mr. Schipper's reference to the effect on the transmission and clutch bearings of using the engine as a brake. It seems to me that this use of the engine is necessary, even though we do have sufficient heat-dissipating design in the brakes themselves, especially on steep grades. If the transmission is in second, in low or even in high gear and the skid starts, to let the clutch back in and start the wheels revolving gives a much greater factor of safety in descending a steep hill than if the gears were in neutral. If the transmission and clutch bearings are of sufficient capacity to drive a car up a steep hill without becoming overheated, why is it that they cannot take the reverse thrust?

One weakness in the design of some brakes is the tendency of the anchorage to break; that is, the point at which the brake-band is secured and prevented from revolving when the brake is applied.

WILLIAM R. MCCULLA:—In regard to using the engine as a brake, I have had considerable experience in contest work in endeavoring to get a large number of miles per gallon of gasoline. In one recent test a light car traveled 106 miles per gal. under official supervision. The previous day it traveled 114 miles per gal. I have been advised that this car can travel 160 miles per gal., but this is accomplished by stunt driving. Another make of car that was attempting to beat this record recently was equipped with an over-running clutch, which was most satisfactory. Most of the economy was obtained by changing the gears into neutral and coasting nearly ¾ mile after a certain speed had been attained. In driving in the mountains, if the engine is used as a brake, the gasoline consumption is increased very materially. Provision should be made for proper brakes instead of depending upon the engine. In one English car, when the engine was used as a brake, the carbureter admitted pure air instead of a mixture of gasoline and air. This was of great assistance in cooling when driving in mountainous regions and, of course, it did not increase the gasoline consumption or affect the lubrication by sucking raw gasoline through the combustion-chamber.

N. L. DOD:—The insurance interests are considering using the acceleration and deceleration values for liability insurance against collisions. The present high-priced values are due to the fact that the dollar-for-dollar value of materials in cars seems to be about an average.

The formulas that have been submitted are too complicated or have indeterminate values that involve a judgment factor, to be determined by the man doing the rating, which of course is not advisable. We have made experiments with four-wheel brakes and find that in going down-hill the greater proportion of the load of the car is transferred to the front-wheel brakes; so, if the front-wheel brake-drag with a certain weight of car is of the same capacity as the drag on the rear-wheel brakes, the breaking efficiency probably would be 50 per cent greater than with the same total braking capacity on the rear wheels alone.

PROPELLER-SHAFT BRAKES

CHAIRMAN H. W. ALDEN:—Mr. Schipper says that propeller-shaft brakes are coming in. I think there is no doubt about it, particularly on the smaller and lighter cars.

K. G. HOWELL:—My experience with propeller-shaft brakes covers some 30,000 miles. During that time I have never had a particle of skid caused by the application of the brake, which has a drum 12 in. in diameter and about 3 in. wide. I have had some trouble with brake-lining, but one company manufactures a lining that is entirely satisfactory. I have found that a transmission brake is most satisfactory on the average road. I usually drive at an average speed of 45 m.p.h. and my experience covers 6 years. The transmission brake can always be depended upon on a wet, slippery surface and on a turn. It has the easiest type of adjustment; a small wing-nut adjustment is necessary only once in about 2000 miles of travel.

R. W. A. BREWER:—It seems to me that an engine is for propelling a car and that a brake is for stopping it. It surely is within the province of the engineer to design some mechanism that will operate satisfactorily for the purpose for which it is designed. In this country we are more familiar with the type of brake that is attached to the rear wheels, but there is some interest now in the direction of a proper propeller-shaft brake. I endorse what Mr. Howell has said about the propeller-shaft brake. From many viewpoints it opens possibilities for good engineering design that cannot be attained in the ordinary type of rear-wheel brake. To mention a few of these points, one is the variable amount of friction that cannot be avoided with the rear-wheel type of brake. This friction varies with weather conditions. For example, one cannot depend upon getting the brake into effect when the brake-bands become wet. Furthermore, in many designs of the rear-wheel type of brake, the adjustment and consequently the braking effort vary with the number of people in the rear end of the car. That makes it always a matter of more or less uncertainty how the brakes will operate in an emergency. With a propeller-shaft brake those conditions do not obtain; one always has the same coefficient of friction on the brake-drum. In many designs one can adjust the brake-drum from the driving-seat, which is an advantage in mountainous country.

In hilly countries the problem is entirely different than in the major portion of American motoring, but we must design cars for any sort of condition that reasonably may be expected. One cannot say that because 90 per cent of the cars run on smooth, level roads the other 10 per cent can be neglected. During four years of driving in California I used four different cars and believe that not one of them delivered what should reasonably be expected from a reliable braking system. The brakes could not be depended upon to operate through a day's run without cooling them in a stream or using the engine as a brake. Acting as referee for the American Automobile Association Contest Board in California on reliability runs, I have penalized the drivers in many cases for doing the very things that I mention. The standard cars would not negotiate the grades met in an ordinary day's run without the necessity for stopping and doing something to the brakes.

SANFORD EVANS:—The brake is primarily a means of dissipating, as heat, the energy that is stored up in a car when it has gained a certain momentum, but many braking systems seem to indicate that we have forgotten this. Many of the present brakes will stop a car readily enough and many engineers test cars on the basis of attaining a certain speed, applying the brakes and seeing how quickly they will stop the car. It appears to me that the reason we use the engine as a brake is that ordinary brakes will not withstand the constant drag that obtains in going down a long hill. The energy stored in the car requires sufficient heat-radiating surface. Almost any brake-lining will overheat. In my opinion, it injures an engine to run it at high speed when driving down-hill with the ignition either shut off or on. We would not open the throttle when the car is standing still and let the engine turn over at 1200 or 1500 r.p.m. under absolutely no load. I believe that braking with the engine causes even more harm than idling the engine at a high speed. If the transmission brake, which is probably the only "equalizer" that approaches perfect equalization, can be designed to radiate the heat that must be dissipated through the brake, it is a promising medium of experiment.

H. M. CRANE:—Mr. Schipper reproduced in Fig. 25 of his paper a brake design that we recently developed, and I wish to explain the principles upon which this brake design was evolved.

For a smooth-acting friction-device of any kind, the thing of greatest importance is low unit-pressure. That is attained in a variety of ways, such as having large areas or having the areas traversed at high speed. That is an advantage obtained with the transmission brake that operates on American cars, at from 3½ to 5 times the speed of a rear-wheel brake. It is attained also by being certain that the apparent pressure is uniformly distributed over all the braking surface. That is one of the most important considerations and it is where the shoe type of brake invariably fails. It is a place also where many of the band brakes fail, due to a design of anchorage, that causes a wedging at the anchorage, or to a design that creates excessive pressures at the point where the bands take hold.

On the service brake we have only 4 to 5 in. of pedal motion with which to work. If we use more pedal travel, the car becomes uncomfortable to drive. We also have a limiting pressure. We are limited to a pressure that can be applied by a driver comfortably. Many drivers are women who are neither heavy in weight nor powerful in muscle. We must see that this 4 to 5 in. of pedal motion is transferred in the form of motion and multiplied to the necessary amount at the friction surfaces without loss. If there is springing of the parts or lost motion, in just that degree we are reducing the possible multiplication that allows the use of a low pedal-pressure.

On the transmission brake shown in Fig. 25 of Mr.

Schipper's paper, the actual figures on a 5500-lb. car weighing 6000 lb. with a normal number of passengers show that it will slide the rear wheels of the car with less than 50-lb. pressure on the brake-pedal. Part of this result is due to the fact that the entire multiplication is obtained at the point of application of the power, so that there is practically no strain in the controlling parts; part is because the rear-axle ratio is 4 to 1, which gives a very high peripheral speed on the drum; and part is for the reason that the drums in question on this transmission shaft are as large in diameter and area as the rear-wheel drums on many American cars of 5 or 6 years ago. They are not so large in diameter as some rear-wheel brakes on the present cars, but they are as large as one can locate safely under the floor of a car, and that is where the transmission brake must go.

As a designer of heavy cars, I say that the idea that a brake can be or should be designed for maximum possible conditions in mountainous countries without the assistance of the engine is an impossible consideration. With a car weighing 3 tons in its running condition and figuring the amount of heat that must be dissipated, the result shows immediately that no size of drum that can be placed readily in the car, even with the assistance of water-cooling, can be expected to take care of the braking requirements. On the other hand, in the well-designed engine we have everything present that is needed to make a good brake. The resistance of an engine turning at high speed with the throttle closed, as it should be in braking, is very largely due to the pumping action of the cylinders. In other words, we have a reversed airbrake. We have an efficient oiling system taking care of all the moving parts. We have a radiator that might as well be used and that would otherwise be doing nothing. There is no question that this can be done with impunity in a well-designed engine. I have records of cars used in Alpine work where no difficulties of any kind ensued when using the engine as a brake; there were no oiling troubles, no excessive wear and no troubles of any other kind. There is probably enough room on very small cars to put on brakes that will do the work.

To revert to the small amount of pedal motion available, this increases very greatly the efficiency of the transmission brake as compared to rear-wheel brakes because one deals with a single set of operating parts and not two sets. The multiplication of the number of operating parts means more lost motion, and makes it impossible to use the same degree of multiplication that one would use on a single set of parts. To go further, I call attention to the serious effect that this has on the attempt to use four-wheel brakes. With four-wheel brakes it is almost impossible to get the adjustments such that the braking system is really efficient, unless this is done by experts. I think that the four-wheel brake is not desirable in any sense for the average man and that, in the main, it will result in more accidents than it will ever prevent.

L. F. Howard:—Recently, we have developed an air-brake for automobiles. Will Mr. Schipper give his reasons for saying that "the hydraulic system probably shows the greatest promise at present because of its simplicity and also from the standpoint of perfect equalization"?

Four-Wheel Brakes

F. S. Duesenberg:—I do not agree with Mr. Crane that four-wheel brakes might be the cause of more accidents. I feel that a four-wheel brake is likely to avoid accidents, provided it is kept reasonably well adjusted and equalized.

I made a trip about 2 years ago that included many hills from 3 to 4 miles long, with a standard car having two rear-wheel brakes. The emergency brake had an inner and an outer band. In going down hills I would use one brake until the drum was red-hot; then I would apply the other brake and burn that lining. When I approached the bottom of the hill I had no brakes and, consequently, I used the engine as a brake. The car was not in the best of condition, but the trouble was that a large quantity of oil was pumped. I was pretty thoroughly disgusted with the two-wheel brake. When we decided to adopt the four-wheel brake, the first trial was made on those same hills. In going down we found that we could travel at any desired speed and when we reached the foot of the hill the brakes were no hotter than would allow one to hold one's hand on the drums.

We are using drums that are drop-forged and rather expensive to make. We rib them very heavily. In that way we get a cooling capacity that we consider is 10 to 12 times greater than one can possibly get on a two-wheel brake having an inner and an outer band; with the latter type one cannot get rid of the heat. We are using a hand-lever with the propeller-shaft brake, but have experienced some trouble. We did not realize at first how great the pressures and service are that are put on the bearings and the other parts that are connected to the propeller-shaft. However, after the test we have made recently, we feel satisfied that this is only a point of minor importance and easy to overcome.

We feel that we can stop a car with four-wheel brakes in practically one-third the distance required with a two-wheel brake. That is true particularly on slippery pavement. Many say that the four-wheel brake should give different service front and rear. We did not consider that of any importance at first but after experimenting decided to put a stiffer spring on the front brakes so that the rear brakes would be applied first. Since we have been doing that there has been absolutely no objection to the braking.

We have tried the transmission brake on some long hills. Unless one uses metal lining, which I think is objectionable in most cases on account of the noise, there is a considerable tendency toward burning if one uses no other brakes. We never use the hand-brake except for locking the car. Many things can be said in favor of the hydraulic brake, but I believe that a mechanical brake, properly applied and possible of being equalized easily, should be about as satisfactory as a hydraulic brake, except that the hydraulic brake eliminates many moving parts and lessens the chance of unequal braking.

Brake Area Formula

E. Favary:—The practice of manufacturers of announcing in their literature that their cars are equipped with a certain brake area, gives no indication of the efficiency of the braking system. Unless it is known how far this brake area is located from the center of the wheel, it is impossible to find the effort required, or the necessary pressure between the brake-band and the brake-lining to lock the wheels. For this reason I think that the formula for finding the diameter of the brake-drum, given in Mr. Schipper's paper, is of little value to the designer. I present two examples to show how misleading any formula is that enables us to find only the brake area, assuming in one case a brake width of 1¾ in. and in the other case a width of 2½ in.

With a brake width of 1¾ in. and a maximum car-weight of 4000 lb., we have according to Mr. Schipper's formula.

$\{[(4000 \times 0.045) \div (2 \times 1.750)] + 1.500\} \div \pi = 16.800$ in.

This is the diameter of the drum. If the brake width is 2.5 in., the drum diameter is 11.9 in. The surface area of the brake is approximately 90 sq. in. in each case, but the brake-drum diameters differ greatly. Assuming the wheel diameter to be 34 in., the radius, R, then being 17 in., and the load on each rear wheel to be 1250 lb., when the wheels are locked there is a pull at the surface of the tires of 1250 x 0.6 = 750 lb., where 0.6 is the coefficient of friction between the tire and the road surface. The torque created by the wheel is $750R = 12{,}750$ lb-in. To find the force required at the periphery of the brake-drum to lock the wheels, the torque must be divided by the radius of the brake-drum, which is 8.4 in.; hence, this force is 1514 lb. If the coefficient of friction between the brake-lining and the brake-drum is 0.25, the normal pressure between the brake-drum and the brake-lining in $1514 \div 0.25 = 6056$ lb., and the actual pressure is $6056 \div 90$, or 67 lb. per sq. in. approximately.

In the second case, where the brake-drum diameter is 11.9 in., we find a pressure of 95 lb. per sq. in. between the brake-lining and the brake-drum by carrying the calculations through in the same manner. This is almost 50 per cent more than in the first case, while the radiating surface, that of the flange attached to the wheel, is smaller by $[(0.7854 \times 16.8^2) - (0.7854 \times 11.9^2)] = 110$ sq. in. Hence, the lining will wear-out sooner, the drum will become hot more readily and, if the operating linkage is the same, the foot-pedal pressure would need to be 50 per cent greater to lock the wheels. I think that a much better indication of brake efficiency is the pressure per square inch between the brake-lining and the brake-drum that is required to lock the wheels when the car is fully loaded and traveling on a level road.

A. M. WOLF:—In the Saurer construction the engine has a sliding camshaft that alters the normal operating cycle of the engine and makes it more efficient for braking purposes.

At the end of Mr. Schipper's paper reference is made to motor-truck brakes. In this connection I firmly believe that, where a large amount of energy is to be absorbed in the brake, the Mack and the White construction of making the brake a separate unit is very commendable. In this way the brake can be supported adequately at each side by a bearing and great rigidity secured, which is not possible in the ordinary overhanging propeller-shaft brake.

On some cars using a torque-tube and a transmission brake the universal-joint is relieved of braking stresses by placing the brake to the rear of the joint, supporting it by the front end of the torque-tube instead of by the transmission.

We find two forms of construction in the mounting of the brake-drum on the rear-axle hub. I believe that we should mount the drum adjacent to the integral flange on the hub that, necessarily, must be toward the inside in this construction. Where the flange is on the outside, the drum is bolted against the wooden hub of the wheel. This cannot be relied upon for such accuracy as when it is mounted adjacent to the integral flange.

The ordinary stamped brake-drum is, in many instances, lacking in concentricity, which of course prevents proper brake operation. Sometimes the braking surfaces of the drum are machined, which insures proper operation. Where the expense is permissible, there is no doubt that the best construction is obtained by the use of the forged drum with radiating ribs on the exterior, which stiffens the drum at the same time; also, the braking surface can be machined or ground.

Mr. Schipper's paper makes no mention of the multiple-disc type of brake, such as was introduced by Lanchester in England and by Metz and Parker in this Country. Sufficient surface is obtained easily by this method, and I believe it has great possibilities. Located at the back of the transmission, where there is plenty of room, and where it also becomes unsprung weight, this construction should make an ideal service-brake.

Care should be used in the lubrication of the brake rigging. The practice of locating grease-cups where they are absolutely inaccessible should be replaced by other construction such as the use of self-lubricating bearings.

Two other methods of energy absorption have been used. These are the Saurer fan brake that dissipates energy in a similar manner to that of a fan dynamometer, and the hydraulic method as exemplified by a construction in which the constant-mesh gears of the transmission are encased so as to form a gear pump, braking being secured by a valve retarding the flow of oil between the inlet and outlet of the pump.

J. E. SCHIPPER:—Mr. Dod spoke of the greater efficiency of the front-wheel brake when four-wheel brakes are used. The efficiency of the front-wheel brake is not determined exactly by the division of weight between the front and rear axles. The front-wheel brake has the effect of the forward rotating movement in addition to the weight of the car. This tends to throw the car over on its forward end when the front-wheel brake is applied, and that is a very considerable factor. In a number of the letters received on four-wheel braking I notice that the engineers believe that the front-wheel brakes should be made a little less efficient than the rear-wheel brakes to facilitate steering. It is noticeable that a man who is accustomed to rear-wheel brakes alone will have trouble in steering if he tries to apply his brakes at the time he is rounding a corner, as he would do when operating rear-wheel brakes. This will tend to throw the car into a kind of front-wheel skid. After practice he will apply his four-wheel brakes before he reaches a curve.

With reference to Mr. Evans' remarks on using the engine as a brake, how many of us would like to drive our cars in second gear at the rate of 20 to 25 m.p.h. for any extended length of time without something to hold the transmission from jumping out of the chassis?

In answer to Mr. Howard's question on hydraulic brakes as compared with airbrakes, I might amend my paper to read, "a fluid system," instead of "hydraulic," because the principle that I wanted to bring out applies equally to air, water or oil. I wished to emphasize that in a fluid system the pressure is balanced at all points by the very nature of its fluidity, this providing equalization.

DROP-FORGING PRACTICE

BY J. H. NELSON

THE author discusses drop-forging practice from the standpoint of the materials used, and strongly advocates a more rigid inspection and testing of raw products to determine their fitness for use in making automatic forgings.

Seven specific possibilities of actual difference between drop-forgings that are apparently identical are stated, the requirements of the inspection of raw stock are commented upon, and the heat-treatment and testing of finished forgings are considered at some length.

Tabular data of the chemical analyses and physical properties of 107 different heats of carbon-steel used recently are presented and show a variation in drawing temperatures of 140 deg. fahr. in steels of practically the same chemical composition to meet the same physical-property specification, based on more than 1000 tests on this grade of steel taken from production stock. The concluding summary has five specific divisions.—[Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

J. H. NELSON:—We have found from our experience in producing quality drop-forgings that it is not safe to say that all steel conforming to a certain chemical specification will respond in exactly the same way in all heats of that particular grade. In fact, we have found from our experience that the result is contrary to that. That a steel is classed as a 0.40 to 0.50-per cent carbon-steel does not mean that a melt of this particular steel will respond in a like manner to one from the next shipment received from the same or another mill. To minimize our losses in the shop and give our customers the quality they desire, we have found it absolutely necessary to inspect very closely and to keep segregated throughout the yard and shop, every melt of steel that is received from the mill. Within the last year, I have been keeping accurate records of our operations to determine exactly whether our losses are due to improper heat-treatment or whether they are chargeable to the steel. I have compiled the information given in this paper from these records, thinking that it might be of some assistance to others who find their heat-treatment losses running rather high.

The two causes of heat-treatment losses are imperfect or mixed stock and imperfect equipment. We are satisfied that, while our heat-treating equipment is not perfect, it is far above the average and tests made on production work have proved that with a uniform heat of steel we can turn out a uniform product. We have eliminated the personal equation by placing our furnaces under automatic control so that the over-running of heat is eliminated. Therefore, to study these losses, we have kept accurate records of the Brinell-hardness of every piece treated, as well as of the physical tests on each furnace-charge. From these I have compiled the results given in Table 1, which includes 107 different melts of steels received from a number of steel mills. I have grouped these according to the draw heat necessary to meet a definite specification. We have found, as shown, that in order to minimize our losses it is necessary to draw from 980 to 1120 deg. fahr. and to keep within the Brinell-hardness limit specified, namely, 228 to 248. To emphasize that more forcefully, Table 2 summarizes the results of Table 1, giving the average of both the chemical and physical properties of the different groups and showing the number of tests made.

Better physical properties could be produced on these steels if we were allowed a higher Brinell hardness. However, it is to be noted that the average, representing nearly 1100 tests, gives a variation between the maximum and the minimum elastic-limits of about 5000 lb. per sq. in., and in tensile-strength a difference of about 6000 lb. per sq. in. This is conclusive proof that the draw heats used were necessary to bring these steels to the common basis. It is also to be noted that the Brinell hardness of these steels is very close.

This demonstrates clearly the dangers of attempting to draw conclusions from a single melt of steel. If some one had been investigating 0.40 to 0.50-per cent carbon-steels to produce certain results and had used a melt of steel from Group *A*, his conclusion would have been that 980 deg. fahr. is the necessary drawing temperature on all 0.40 to 0.50-per cent carbon-steels to meet this definite specification. If another investigator had been using Group *H*, he would have arrived at an entirely different conclusion with respect to draw heats; so, in discussing the relative values of steels, to my mind it is very necessary that a large number of different heats be investigated, in order to determine the average condition that can be obtained. Nothing of conclusive value can be produced from a few tests on a single heat or melt.

R. H. SHERRY:—In what type of furnace were these draw heats made?

MR. NELSON:—In an under-fired furnace.

MR. SHERRY:—In drawing hardened pieces of the nature of crankshafts we have got away from some of this variation in Brinell hardness and in the physical properties of the same type of steel by the use of the lead pot on a large scale, one from 6 to 7 ft. long and 20 to 24 in. wide. Of course, we do have the variation that Mr. Nelson mentions, but I wonder if there is not some further chance for research along this line that will give a direct comparison. These data are very valuable from the furnace standpoint, but so far as I have been able to ascertain, it is very difficult to obtain a uniform draw in the several varieties of furnaces that seem to be uniform in control. By the use of the lead pot with its exact temperatures, in the case of heavy pieces using two pots and carrying from one to the other, we have been able to hold that range considerably closer than I notice has been done in this particular type of furnace. Has Mr. Nelson had experience along that line and is that not a factor in the variation of the figures?

MR. NELSON:—I am a firm believer in the physical properties, including Brinell hardness and functions of temperature, rather than in the means of obtaining that temperature. To my mind it is immaterial whether one uses a lead pot, or an electric, gas, oil or other type of furnace, provided one produces the temperature with which one is working. These furnaces are balanced very carefully before they are turned over for production work. They are balanced by using pyrometers that have been checked accurately. A pyrometer is placed in each corner of the furnace, which is the part most difficult to heat, and also in the front and in the rear center of the furnace. These six pyrometers must agree within 5 deg. before the furnace is turned over to production work.

In our control we have furnaces that are run by two pyrometers; one in the front center and one in the rear center. We can throw our control instrument on either fire-end. When a charge is pulled and a new charge is put into the furnace, the front of the furnace cools down more rapidly than the rear and the control instrument is thrown on the rear end when the furnace starts up. A two-point recording instrument shows a slight variation between the front and the rear until the desired temperature is reached, after which the two fire-ends run a straight line, which demonstrates clearly that we are actually holding to the temperatures indicated.

MR. SHERRY:—I realize that Mr. Nelson has perfect control in those furnaces because I have heard much about them but, regardless of pyrometer control, we had an experience with a certain type of furnace that was absolutely uniform. I ran it with six or seven thermocouples under different portions of the furnace and yet obtained variations. There are other factors beside pyrometric control. For instance, with two large sections piled one on top of the other, which sometimes occurs, it

takes longer to heat through from steel to steel than it does to heat with a direct application of the heat to the surface of the steel. I mention this as being possible. I found variations in the very best types of furnace, those having the most uniformity.

W. F. GRAHAM:—Without questioning the accuracy of the control that Mr. Nelson mentions, which is undoubtedly very good, I support Mr. Sherry in his idea that lead-pot furnaces do give a remarkable accuracy compared with any other type in which the heat is not conveyed to the metal by molten metal. My experience on fairly large forgings running in the neighborhood of 0.35 or 0.45 per cent carbon has been that the most accurate results are obtained when those forgings are quenched from a lead pot and drawn in a lead pot. The more intimate contact of the heating medium with the work, particularly when it is put through in a commercial way and there is more than one piece in the pot, gives a more uniform hardness.

Are not these variations that Mr. Nelson mentions, variations in hardness that will occur unless one varies the drawing temperature, a function of the carbon and the manganese-content of the material? With both the carbon and the manganese on the low side of the specification, one cannot expect to get the same result as when one has them both on the high side. This comes back to the old argument that is advanced for a five-point range in carbon, which we know is practically impossible to obtain on a commercial scale from the steel companies; in fact, the heats will not run as uniformly as that in many cases. My experience is that it is absolutely necessary to take into account the percentage of carbon and manganese, and to vary the drawing temperatures accordingly over a range of about 200 deg. in medium-carbon steels. In this connection I have found that on hardened and drawn work covering the range of S.A.E. No. 1035 steel, at about 0.30 per cent carbon there is a very sharp drop in the hardening power. If the steel runs a little below that in carbon, with the manganese down fairly well, one cannot expect to get good results. One practically would need to eliminate the draw to obtain the average specification of hardness on which one is working.

With the S.A.E. Standard range of 10 points of carbon and the manganese from 0.50 to 0.80 per cent, although Mr. Nelson says he uses a manganese range of 0.60 to 0.80 per cent, I have found that the drawing temperatures necessarily will be varied in proportion to the manganese and carbon-contents for all practical purposes, unless the work is put through in individual heats, which is the desirable condition. On small lots I have made it a practice to divide the work into three classes; to take a 0.30 to 0.40-per cent carbon-steel and group the heat into three classes, from 0.30 to 0.33, from 0.33 to 0.37 and from 0.37 to 0.40 per cent, taking into account the manganese-content. How does that correspond with Mr. Nelson's idea of it?

MR. NELSON:—The chemical composition of every individual heat is given in Table 1 of my paper. In Table 2, which is the average of the chemical composition in the various groups as well as of the physical properties, we find the variation in carbon-content from Groups *A* to *H* to be 0.43 to 0.47 per cent. The averages being so close must mean that the carbons in the particular group are very nearly the same or that there is a certain proportion in each group that is high and a certain proportion that is low, to give us the same average; consequently, it is sufficient to examine Table 2. Hence, we find a variation in carbon from 0.43 to 0.47 per cent.

In manganese, we find a greater variation. Group *A* is 0.65 and Group *H* is 0.77 per cent but, if we eliminate Groups *A* and *H* and compare from Groups *B* to *G*, we find from 0.69 to 0.75 per cent is the maximum variation. The fact that a steel is analyzed and found to contain about 0.40 per cent carbon and another contains 0.50 per cent carbon does not mean at all that the one which contains 0.50 per cent carbon will require a higher draw than the 0.40-per cent carbon-steel.

MR. GRAHAM:—In Table 2, have Groups *A* and *B* as compared with Groups *G* and *H* received the same quench and the same draw?

MR. NELSON:—Groups *A* and *B* have received the same quench but Group *A* is drawn at 980 deg. fahr.; Group *B* is drawn at 1000 deg. fahr. to meet the required specifications. We use the same quench on all these steels.

MR. GRAHAM:—Is that a standard treatment or is it varied with each individual heat?

MR. NELSON:—We investigate every individual heat and determine what heat-treatment it must receive.

MR. GRAHAM:—Then this is really an average of the heat-treatments as well as an average of the other results?

MR. NELSON:—Group *A*, as given in Table 2, is an average of six different heats of steel in Table 1. All these different melts of steel in Table 1, Group *A*, received a 980 deg. fahr. draw to comply with the specifications, and so on throughout. It was absolutely necessary to use that heat because, if drawn at a higher or a lower heat, one would lose a certain percentage of the product. This is the best average heat we could get to maintain a minimum loss.

With regard to Mr. Sherry's remarks, we do not pile materials in our furnaces. Materials are put into the furnace in an orderly manner so that we can get a uniform heat. I agree with him that, if materials are piled in a furnace, uniform heating is difficult to attain. Our furnace charge is not a hit-or-miss proposition; it is composed of crankshafts of the same kind. One row is placed across the hearth of the furnace in the rear and another across the hearth of the furnace in front; there is no piling.

MR. SHERRY:—That particular case I mentioned was rather a form of illustration. I believe that if one should look into the average drawing furnace, where the product is at a visible red heat such as I have seen on crankshafts calling for higher temperatures on the draw heat, even with the best regulation one would see some variation in the color indicating a variation in temperature, merely from a slight change in the position of the shafts. It does happen. On the Liberty-engine crankshaft, drawn in a very accurately built furnace giving a high degree of heat uniformity and held under thorough control, it was found necessary to run many through a second time.

H. J. STAGG:—Mr. Nelson has told of variations that occur, but it seems that these variations do not occur in his shop. The conclusions that the steel manufacturer must reach is that the variations are due to manufacture. Has Mr. Nelson any thoughts on the why and wherefore of these difficulties he has pointed out?

MR. NELSON:—I look upon steel manufacturing as being very much on the same order as bread baking; that is, the chemistry of a loaf of bread may be perfect but in the baking of that loaf of bread, if the heat is raised a little too fast, is too high or not high enough, one would not get good bread. In the same way I believe that the matter of heating and other things in furnace control that influence the making of a heat of steel have a decided effect on the physical properties of the steel pro-

duced. We will occasionally get a heat of 0.40 to 0.50-per cent carbon-steel that will give exceptionally high values. We will then get another heat of steel that we cannot use; both will analyze perfectly, chemically. Again, we will get a heat of a 0.30 to 0.40-per cent carbon-steel that will give us better physical properties than can be produced with the average 0.40 to 0.50-per cent carbon-steel. But it has so happened, I believe, that there was a balanced condition in the furnace. The steel manufacturer probably knows just what that balanced condition is.

MR. STAGG:—Has Mr. Nelson been able to detect any difference in the raw materials coming from the mill; that is, any physical or microscopic difference in the material with which he started that would enable him to predict what result he would get, what the material would do? One must be able to tell what that difference is; things are not so intangible that we cannot determine them.

MR. NELSON:—I agree with Mr. Stagg, although I am not ready to state what the difficulty is. However, I am keeping very accurate records as to the practice of the different mills in addition to these other records. We find that Mill *A* will invariably require a low heat, Mill *B* will require a high heat and Mill *C* will strike a middle point; that is, for the same identical chemical composition, there is a difference in the practice in the different mills such that one can trace them in that way.

C. N. DAWE:—With regard to this variation that Mr. Nelson mentions, I note that his Brinell hardness is held to about 10 points in all these tests; in some classes of our work we allow a range of 50 points in Brinell hardness. If we decide on a certain draw heat for a particular class of steel, the variation in the Brinell hardness may be as stated; but, if we tied it down to 10 points, we would need vary our draw heats too much.

In answer to Mr. Stagg, I would say that I have seen a heat of crankshaft steel that had the proper chemical composition and, so far as we could find out, was metallurgically correct, but we could not harden it. A representative of the Carnegie Steel Co. tried two or three times to harden these crankshafts; he even used special care to pick out the crankshafts that fell midway between the limits, but we could not harden them. The company took some of the crankshafts back to the mill, and stated that it could not answer the question. The peculiar thing about it is that, after the crankshafts lay around the yard for a number of months, we treated them and they came through all right. Recently, we have heard of the seasoning of forgings. There was a claim current that by allowing gear forgings to season for a certain length of time, much of the warpage would be eliminated. It is logical to assume such a thing. I can vouch pretty well for the furnaces that we ran the crankshafts in later; they are very carefully watched and checked. Those are the facts of the case. The point I was trying to bring out is that there was apparently no method of accounting for the action of this particular heat. I have heard of taking heats that have been allowed to stand in the open hearth longer than they ought to; but one cannot get the results out of those particular heats, although one perhaps may never detect it in the analysis. I am not sufficiently informed in that direction; there may have been something of that nature which caused it.

MR. SHERRY:—Did Mr. Dawe use oil or water in quenching crankshafts? I presume Mr. Nelson used water.

MR. DAWE:—We used temperatures on 0.40-per cent carbon-steel from 1525 deg. fahr. up, and went as high as 1700 deg. fahr. to harden this particular heat without success. Water was used as a quenching medium in this particular instance.

MR. SHERRY:—We experienced the same thing in that stock and found later that we could put it through, but I believe Mr. Nelson is referring to current practice day in and day out.

THOMAS H. WICKENDEN:—I had a similar experience that bears Mr. Nelson out. During the war we made a large quantity of road track links for tanks. The steel used was of the same analysis that we are dealing with here, the physical properties required were similar and, if I recall correctly, the Brinell-hardness limits were the same. The lower Brinell-hardness limit placed on it by the Government inspector was 228; the upper limit of 248 was placed on it by the shop to eliminate trouble in machining. Rockwell furnaces of the latest design were used in which the temperature throughout was found to be very even. The heats were controlled by pyrometers and we feel reasonably sure that our temperature readings were accurate. The men handling these furnaces are doing it every day and become expert at it. We kept a record of the number of links that were inspected for Brinell hardness that would pass within the specification the first time and, after a little experience, 98 and 99 per cent of these links would pass inspection with one drawing heat. We found that low carbon and low manganese will explain much of the difference required in drawing temperatures, but we also found heats with exactly the same analysis that would require a drawing temperature perhaps 100-deg. fahr. higher than with another heat of steel to secure the same properties. We found also that, by using the same temperatures on batches from the same heat, we duplicated our results without much difficulty.

MR. NELSON:—I wish to confirm what Mr. Dawe said with regard to heats that are wild. We find those occasionally, not only in the carbon-steel, but in chrome-nickel steel. In our inspection work we have adopted the practice of using a 2½-in. coupon; it is Brinelled on the outside and, when the coupon is split to cut the test-specimen, it is also Brinelled on the center. Thus, a comparison between the outside and the center Brinell-hardness numbers will account for much of the variation. In other words, there is great variation in the hardening capacity of the same steels. A 0.40 to 0.50-per cent carbon-steel may harden through perfectly; another 0.40 to 0.50-per cent carbon-steel may have very imperfect hardening capacity, and that is true also of chrome-nickel steels. Usually, a chrome-nickel steel or any alloy-steel 2½ in. in diameter will harden through fairly well. Occasionally, we get heats that are simply impossible to harden except to perhaps ¼ in. depth; inside of that ¼ in. the steel is perfectly soft.

CHAIRMAN F. P. GILLIGAN:—The foregoing discussion shows that it is desirable to make preliminary tests before going into heavy production based upon such physical properties as may be published for the purpose of guidance only.

SPECTROSCOPIC INVESTIGATION OF INTERNAL COMBUSTION

BY THOMAS MIDGLEY, JR., AND W. K. GILKEY

THE paper is designed to familiarize automotive engineers with the general subject of spectroscopy, pointing out the various methods that can be employed to determine the actual instantaneous pressures obtained in normal combustion, the temperature-time card of the internal-combustion engine and the progress of the chemical reactions involved in normal and abnormal combustion.

The subject of spectroscopy is outlined and explained, illustrations being presented of different types of spectra, and spectroscopes and their principles are discussed.

The remainder of the paper is devoted to an outline of what the spectroscope can reveal about the nature of combustion. [Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

THOMAS MIDGLEY, JR.:—In our mental picture we always have imagined that the high pressure area of the wave-front of detonation was a hot luminous region; that, necessarily, high pressures were in regions that were hot, consequently luminous, and therefore that they could be studied with a spectroscope. The spectroscope is of little use in studying cold and non-luminous gases. Recently we have done some work which seems to prove that the high-pressure portion of the wave-front of detonation is actually cold, and among the unburned gases; that, as the gases burn, the pressure drops. This conclusion has been reached mathematically. The spectroscope will give negative evidence of high pressure under these conditions.

Some optical indications of high pressure have been obtained in our attempts to measure the detonation pressures. The spectroscope was focused to give the two sodium lines of normal combustion as indicated in Fig. 5 of our paper. Photographs were taken under normal combustion without any knock. The plate when developed was found to contain two very black lines. The plate then was remounted in precisely the same position it had when the photograph was taken and a micrometer screw was used so that these two lines might be shifted a little to the right or to the left. The engine then was set to knocking. The sodium lines immediately broadened on both sides of the two black lines. The broadening of a line indicates increase of partial pressure. The shifting of the line bodily indicates an increase of total pressure. These are facts. But we did not see that the line shifted to one side or the other; it simply broadened. The source of sodium in the internal-combustion engine is simply the sodium in the air. We could not use additional sodium.

This result was rather disconcerting; we expected the lines to shift toward the red. By means of the micrometer screw the plate was moved toward the right and toward the left. We found that, while the lines apparently widened on both sides, there seemed to be a sharp position toward the red side where the light changed from an intense yellow to just a dull splash, while toward the violet position this did not appear to exist. Assuming this to be the shifted position, calculations show that the pressure in the flame-front of detonation was either 2960 lb. per sq. in., plus or minus 200 lb.; or 4660 lb. per sq. in., plus or minus 200 lb. The discrepancy between 2960 and 4660 lb. per sq. in. is accounted for on two assumptions: either that the line is narrow or that the line is as broad as the original. This would make the difference. We felt that a photograph would be proof. To get the photograph it was necessary to use a stroboscope in connection with the spectroscope, and to show a portion of the line in synchronism with the crank angle.

A photograph of a single explosion is very difficult to secure. The width of the slit through which light is admitted must be reduced to 0.001 in.; the available light, therefore, comes through a slit 0.500 in. long and 0.001 in. wide. The most sensitive film we could get required 2000 such explosions to give results. A spectroscopic photograph of a single explosion seems within the realm of possibility, but we have not been able to get it yet. Meanwhile, we shall endeavor to show that the high pressure, as indicated by the spectroscope, will be less than that indicated by other means. This will prove that the high-pressure portion is in the cold part of the charge.

Spectroscopic investigation by men properly qualified will yield an enormous amount of data on internal combustion. This paper is presented rather to indicate what things might be found out with proper instruments and methods than to present any new and startling facts.

C. S. RICKER:—Were panchromatic or the ordinary type of photographic films used?

MR. MIDGLEY: — The films were panchromatic when working in the sodium region, because ordinary films are not sensitive to yellow light. Not only was the panchromatic film used alone, but the film was sensitized.

C. H. SHARP:—I question whether the authors have made their point as to the great utility of the spectroscope in the study of these problems. Admittedly, the pressure effect as shown by the spectroscope is very indefinite. As given in the paper, the effect of 12 atmospheres of pressure is to shift a line about 0.1 of an Angstrom unit. That is a very small amount and very careful comparison would be required to determine it. The wave-length of sodium light being about 5900 Angstrom units, a shift of 0.1 unit is about 1 part in 59,000. A very powerful and well-constructed spectroscope would be required to show it at all, and evidently nothing very definite along those lines has been obtained.

We should note that the law on which the measurement of temperature as made by the authors is based is itself based on the assumption that the radiating body is a black body or a complete radiator. When a deduction is made as to the temperature of an alcohol-air explosion-flame on the basis of its being a black body, it seems to me that we are straining things considerably. An alcohol flame, which may be different under high compression, does not approach being a black body in the air; in fact, it is scarcely luminous at all. With a flame containing an excess of carbon like an ordinary oil or gasoline flame, we have conditions which approach black-body radiation. This displacement law may be applied in this way but, for alcohol, certainly, the results ascertained would hardly prove anything one way or another. In that case the radiation would be largely the radiation of water vapor, I imagine. We know that water vapor is

a fairly good radiator in the infra-red region, and very likely it is the superheated steam that is doing a large amount of this radiation.

Why not use the other law of temperature and light, according to which the whiteness of the light emitted increases with an increase of temperature? By putting a stroboscopic disc in front of the window and comparing the color of the light as given out by the explosion with the color of the light of an incandescent lamp having a rheostat in series with it until a color match is obtained, why is it not possible to get a measure of the average temperature of the exploding gases at the instant the window is uncovered by the stroboscopic disc? In other lines of work, we know that a very close comparison can be made between two temperature measurements in this way when the radiating body is a black body or a gray body that is not a selective radiator. Note that I suggest a "color" match and not a "brightness" match as in ordinary pyrometry. I think that the difficulties of carrying out this method would be far less than those of carrying out the determination of the position of the wave-length of maximum radiation, which, after all, is not a very definite thing. One must get the top of the curve, and it is more or less flat-topped, especially in the infra-red; it is not extremely definite, but the color match is a reasonably definite thing and fairly easy to make. It might very well be applied to measurements of what goes on during the explosion in an engine cylinder.

MR. MIDGLEY:—I think we do not differ greatly in opinion, except as to the possible value of continued spectroscopic work. I think Mr. Sharp has repeated some of the limitations I put upon it. On the other hand, except from Henry Lord and Prof. A. Trowbridge, we have received nothing but discouragement from people really qualified to carry on the work. Therefore I ask the members to get behind and push forward instead of getting in front and pushing backward.

E. R. HEWITT:—Has it occurred to Mr. Midgley to sensitize his film in lines, each line being sensitive to a certain wave-length? A number of years ago Captain Abney took photographs of a pot of boiling water in a room at a distance of 10 ft. without difficulty, and the films have been sensitized from the temperature of boiling water. It would be possible to sensitize a film in a series of lines, each one being sensitive to some definite temperature or some particular wave-length. In that way, if photographs were taken as has been described, one would get a series of bright spots on the film sensitized for the particular wave-length. One would be able to form a very good opinion without the use of any other instrument, lenses or prisms. I think that much more accurate results could be obtained in this way.

MR. MIDGLEY:—I shall be glad to try if Mr. Hewitt will send me the references as to where I can find out just how to do it.

A MEMBER:—We ought not to be discouraged because the displacement is small. I discovered a man in Chicago who could divide a wave-length of green light into 1,000,000 parts. I have seen those parts and counted some of them. So I think Mr. Midgley is right. Possibly it may be necessary to call in someone else to help, but he is well within the range of measurement, I think, judging also from the wonderful results Dr. Michaelson has achieved in measuring the flexibility of the earth's crust and in his complete investigations of the tides in the region of the Great Lakes.

MR. MIDGLEY:—There should be no difficulty in measuring 0.1 Angstrom unit. The pressure should be of such magnitude that it would give a shift of 3 Angstrom units. Consequently, 0.1 Angstrom unit only represents an error of about 3 per cent.

J. H. HUNT:—I can add nothing to the data as applied to the gasoline engine, but it is worthwhile to call attention to the fact that Messrs. Midgley and Gilkey are really starting exploration work.

Scientists can raise questions as to the possibilities of this work. Two classes of scientists are doing a great deal of work with spectroscopy. One group is using spectroscopic methods to determine phenomena on the sun and even on the very distant stars, in the case of which no other methods are available. Another group has been studying the relations between the wave-lengths of light emitted under various circumstances by substances under test and attempting to get information from the relation of these wave-lengths that will tell them what the actual structure may be in the atom emitting the light.

There has not been very much work in spectroscopy along lines directly applying to engineering. It will probably result that, as the work is carried farther, Mr. Midgley and others working along this line can take definite questions to the experts in spectroscopy for them to work out. Many of these experts would be just as willing to work on a question in spectroscopy that would have engineering applications as on problems they are attacking. There are many able workers in so-called pure science who are studying problems having no immediate application. They would gladly gather information that we could use at once if the need of solving these special problems were brought to their attention. Therefore, I think that this exceedingly interesting work will be very valuable in the end, because it will bring to some of these scientists questions that they have not thought of, the answers to which would be of very great assistance to us.

Some of Mr. Midgley's work on the anti-knock compounds raised questions in chemistry that the chemists had not answered but were of great interest to the chemists. Encouraging workers in pure science to give more attention to some of the problems having a direct relation to everyday engineering work will contribute greatly to our progress.

CHROME-MOLYBDENUM-STEEL APPLICATIONS FROM THE CONSUMER'S VIEWPOINT

BY C. N. DAWE

THIS paper gives a plain statement of facts regarding the application of chrome-molybdenum steels, as noted by a large manufacturer of automobiles, more than 2000 tons of molybdenum steels of various compositions having been consumed in tests and the manufacture of all the important steel parts such as transmission and differential gears, rear-axle shafts, transmission shafts, steering-knuckles, steering-knuckle pins, and the like. The data of an extensive set of physical tests are given, comparing medium-carbon, chrome-molybdenum, chrome-vanadium, chrome-nickel and chrome steels, and the results are expressed by means

of a merit index, taking into consideration yield-point, ultimate-strength, elongation and reduction of area.

The case-hardening grades of steel are discussed, difficulties that were encountered in the use of the low-carbon chrome-molybdenum steel in this connection being specified. The possibilities of nickel-molybdenum steel for case-hardening purposes are considered, the results so far indicating that it is a strong rival of low chrome-nickel steel, which is considered the best steel for commercial case-hardening at present. [Printed in the January, 1922, issue of THE JOURNAL.]

THE DISCUSSION

R. M. BIRD:—In the comparative tests shown Mr. Dawe refers to chrome-nickel steel; the analysis that he gives corresponds practically to that of steels in the No. 3100 grade. Have any comparisons been made on the basis of the No. 3200 grade?

C. N. DAWE:—No, not in this particular test.

R. H. SHERRY:—Has Mr. Dawe tried any chrome-nickel steel of about 0.35 per cent carbon?

MR. DAWE:—No, not in this test, although I have some information on the subject.

MR. SHERRY:—I ask that because, as a rule, if one runs below 0.30 per cent carbon the results may seem to be somewhat misleading in regard to the merit index. It might be worthwhile to carry this farther with 0.35-per cent carbon chrome-nickel steel for comparison.

MR. DAWE:—It would be interesting to run a series of tests along the same lines as given in this paper on the different compositions of chrome-nickel steels. However, I have applied this formula to a number of combinations of physical properties obtained by others with chrome-nickel steels of both the No. 3200 and the No. 3300 series and the results obtained corroborate certain conclusions that can be made from the tests given here. These results indicate that, as a general rule, the merit-index number increases and decreases inversely with the Brinell hardness. To compare one steel with another, the merit-index figures, apparently, must be compared where the hardness of both is relatively the same. As an illustration, I have a merit-index figure of a chrome-nickel steel of approximately the same composition as the chrome-nickel steel used in this test, except that the carbon is 0.35 per cent and the Brinell-hardness number is 207. This should be compared to the last one given in Table 5, which has a Brinell-hardness number average of 209. The 0.35-per cent carbon-steel has a merit index of 95 as against 73.4, which would be expected because of the higher carbon. Likewise, I have a merit-index number of 88.3 for a 0.24-per cent carbon, 3.19-per cent nickel and a 1.01-per cent chrome steel of a Brinell-hardness number of 248; while the merit-index number of the chrome-nickel steel used in this test, of which the average Brinell-hardness number is 254 as appears on line No. 8 in Table 3, is 65.2. According to our theory, the greater merit-index number is due to the superior analysis.

A peculiarity I have noticed is that a No. 3300 series steel in the neighborhood of 0.25 per cent carbon shows a much greater merit-index figure than a No. 3300 series steel in the neighborhood of 0.35 to 0.40 per cent carbon, provided both have approximately the same Brinell hardness. The former is the only one that approaches the results obtained with chrome-molybdenum or chrome-vanadium steels in this test. If this merit-index formula means anything, does not the above suggest that we may have overlooked something?

MR. SHERRY:—We made a few tests on these steels and found approximately that, if we had about 0.28 to 0.30 per cent molybdenum, the results compared very closely with those of the chrome-nickel steel of about 0.35 per cent carbon. The nickel and chromium contents were a little higher in that sample. It might be well to check that also, because this is at the lower end of that No. 3135 series.

MR. DAWE:—Have you ever applied this formula to your results?

MR. SHERRY:—No. Some other factors do not seem to be covered by the merit index. There are steels which had a rather poor merit index that gave good results under actual production tests; and steels that had a high merit index that gave poor results.

J. H. NELSON:—The Brinell-hardness value of these various steels would add considerable value to this tabulation. Surely the Brinell hardness of chrome-molybdenum steel, having an elastic-limit of 146,000 lb. per sq. in. is hardly to be compared with that of steel having an elastic-limit of 100,000 lb. per sq. in.

In furnishing forgings to customers we are held very closely to Brinell-hardness tests. It seems to me that a fair comparison would be between steels having the same Brinell hardness; that is, it matters little what we are able to produce in a steel with regard to physical properties if the hardness is such that machining is out of the question. We must deal entirely with steels that will give production results. Brinell hardness is a very important factor in the consideration of these results. We agree with Mr. Sherry in regard to the particular chrome-nickel steels selected; the carbon and chromium contents are low. If the chromium-content of this steel were raised, as well as the carbon-content, there would be no difficulty in producing the same result as shown with the chrome-molybdenum steel and, as we find, the same Brinell hardness; but the Brinell hardness which we are allowed to use is such that the full physical properties that can be developed are not available.

With regard to the merit index, the results presented show very clearly that this merit-index equation is far from satisfactory. For instance, the first chrome-molybdenum steel given in Table 2 of Mr. Dawe's paper, having an elastic-limit of 146,850 lb. per sq. in. combined with 55.6 per cent reduction in area, is not so good a steel according to the merit index as the first one reported in Table 5, which is a chrome-molybdenum steel having an elastic-limit of 108,500 lb. per sq. in. and a 62-per cent reduction in area. To my mind the steel given in Table 2 is far superior. I agree thoroughly with Mr. Dawe that reduction in area is a very good measure of ductility. A steel such as that cited in Table 2 is in better condition to resist stress or do work than the latter steel having a merit index of 85. This clearly shows that the merit-index equation should be used with caution.

I cannot agree with Mr. Dawe that there is any definite relation between contraction and impact value. That is dependent entirely upon the particular steel with which one is dealing. One may have a chrome-nickel steel of high elastic-limit and high contraction, but exceedingly low impact value; another steel of identical analysis may produce identical physical properties, with the exception of impact. In other words, one may have a steel of 55 or 60-per cent contraction that will give from 35 to 60 ft-lb. impact value. Another steel may have identical physical properties but an impact value of about 4 ft-lb.; that is, the relation between contraction and impact depends entirely upon the kind of steel with which one is dealing.

MR. DAWE:—I have tried to present some facts regarding chrome-molybdenum steel. The chrome-nickel steel

listed on the last line of Table 3 of my paper has a merit index of 65.2; the average Brinell hardness of all those tests was 234. The chrome-molybdenum steel above has a merit index of 88.3; the average Brinell hardness was 244. These are not far apart, of course, and two or three other combinations might be given.

Regarding Mr. Nelson's opinion that the chrome-molybdenum steel in Table 2 having a 146,850-lb. per sq. in. elastic-limit, is better than that having 108,500-lb. per sq. in. elastic-limit, in Table 5, the merit index of the latter, 85.0, is considerably over the merit index of the former, 72.8. Apparently the ratio between the toughness and the elastic-limit is greater in one case than in the other.

MR. NELSON:—Table 2 of Mr. Dawe's paper does not show a single reduction in area below 54. If we compare the merit index of this table with that of Table 5, we find that the latter is higher. However, I prefer every steel given in Table 2 to those of Table 5. It seems to me that this equation must be improved before it will give a real merit index of steels.

MR. DAWE:—Regarding impact, my conclusions are based upon a test of chrome-nickel steel and, as I have said, may not have been carried far enough, although the conclusions are made on pretty good authority. The impact tests follow the reduction-of-area values pretty closely. When the reduction of area increases, the impact value increases, and vice versa. I made some impact tests on case-hardened steel that indicate the above conclusions.

MR. NELSON:—Mr. Dawe and I agree, but we are talking about different things. He is speaking, I believe, of tests he made on steel from the same melt. Undoubtedly, in the case of steel from the same melt, the greater the ductility is, the greater the impact values. I referred to different heats.

We have made many hundreds of thousands of impact tests and not yet arrived at any conclusion as to their meaning, but we have found that the method of making the steel is a large factor in connection with impact value; that is, we have yet to find a steel made by a basic process, speaking now of alloy-steels and particularly of chrome-nickel steels, that has a poor impact value. In like manner it is rare to find a steel made by the acid process that has a good impact value. The same is true of carbon-steels, but in the reverse order; that is, we find, as a general rule, that we get better impact values with a 0.40 to 0.50-per cent carbon-steel made by the acid process, while the corresponding values with basic-process steel are decidedly erratic and poor. One may get an impact value on a 0.40 to 0.50-per cent carbon-steel as high as 80 ft-lb. but, as a general rule, it will be about 8 ft-lb.; consequently, we have not been able to correlate the impact values with ductility or any other physical property.

G. L. NORRIS:—Will Mr. Dawe tell us whether the tests on the steels reported in the tables were made on rolled bars in all cases, as in Table 3 for 1-in. rounds?

MR. DAWE:—Except for a few tests all the 2-in. square bars were rolled; the others were forged from 2-in. bars.

MR. NORRIS:—How is it done?

MR. DAWE:—On a small hammer.

MR. NORRIS:—What are the different methods of making molybdenum steel? Is it ever made with calcium-molybdenate? Does that give the same results as ferro-molybdenum?

MR. DAWE:—I cannot answer the last questions. All the steel we used was made from ferromolybdenum.

GEORGE WILLIAM SARGENT:—Mr. Dawe's paper presents the features of molybdenum steels from a viewpoint that is very interesting to the automotive engineer and, in fact, to any engineer engaged in the manufacture of equipment and machines in which steel is employed. He represents the consumer of a very large quantity of steel. The automobile is subjected to very severe service; it taxes to the utmost many of the steel parts comprising it. Hence, the suitability of the molybdenum steels for automobile parts is a strong recommendation. The old saying regarding the pudding is the basis of his viewpoint. He has not only eaten, but taken a second helping, perhaps several more. I refer to the tables showing the quality values of the chrome-molybdenum steels in comparison with other alloy-steels and their similarity to quality-value tables previously published.

I call attention to Mr. Dawe's statement regarding the small demand for a steel requiring proper and satisfactory heat-treatment through a wide range of temperature. His position is well taken in view of the modern instruments for controlling heat-treatment. But the automobile builder does not handle large pieces which require huge furnaces and quenching baths, where a wide range of temperature becomes very important. We are at the threshold of the adoption of alloy-steels for huge structures, such as bridges, the parts of which are 60 ft. or more in length and correspondingly large in other dimensions. Furnaces possessing a uniform temperature throughout and capable of holding such pieces are costly and difficult to build. In such instances molybdenum alloy-steels show to advantage through having a wide heat-treating temperature range. We have found this feature most beneficial in making large rolling-mill rolls, gun tubes and other forgings and castings. Furthermore, the saying, "There's many a slip 'twixt the cup and the lip," is all too true in heat-treated-steel products, and the wider heat-treating ranges permissible with these molybdenum alloy-steels, as a whole, add to the assurance of the quality of the product.

By "cracker shearing" I presume Mr. Dawe refers to the shearing employed on drop forgings where a trimmer die is used that leaves the forging with a flange or flash, or in some cases a tear extending a slight distance into the body of the forging. Such pieces are liable to develop hardening cracks, particularly if the steel contains hardening elements to such a degree that it hardens too intensely. Hence, as Mr. Dawe points out, there is need to use steel containing limited amounts of carbon, chromium and molybdenum, as well as manganese, phosphorus and sulphur, in such forgings as are to be heat-treated.

Referring to case-hardening grades, chrome-molybdenum steel gives a very tough and strong core with a very hard case when heated to 926 deg. cent. (1702 deg. fahr.) and quenched in oil after having been carbonized at 900 to 926 deg. cent. (1652 to 1702 deg. fahr.). When drawn at 400 deg. fahr., this toughness is increased. The high temperature employed to quench increases warpage and, as Mr. Dawe points out, is commercially impractical with pieces of irregular shape and non-uniform section, such as gears. It is presumed that this is partly on account of the injurious effect of such high temperatures upon the metal pots containing the lead or salt baths.

Nickel lowers the Ac_1 point of steel and this, no doubt, caused Mr. Dawe to turn to nickel-molybdenum steel in order to preserve the good features of molybdenum. I should like to see what results would follow the use of manganese instead of nickel. Its effect on the Ac_1 point is very marked. Molybdenum has a counter effect to that

of manganese, the latter tending to narrow the heat-treatment range and increase grain-growth, producing brittleness. Such steel, in view of the lower cost of manganese, would be less expensive. I suggest that the manganese content be around 1.20 per cent and that the quenching medium be oil or warm water.

Mr. Dawe calls attention to the better case-hardening properties of steel containing molybdenum, and states that a rolled bar carburized and quenched in oil will show greater hardness than any other hot-rolled steel so treated. Might not this characteristic of the molybdenum steels be due in part to their greater freedom from scale? He notes that they forge easily and that the scale formed breaks away readily. In hot-rolling also this tendency of molybdenum steel to free itself from scale is marked, and cleaner steel would carburize more readily. The greater hardness of molybdenum chrome or manganese carbide would account for the further difference in hardness noted. This feature offers a field for the production of hot-rolled, case-carburized and hardened parts with little or no grinding or further work. Such parts, when used in crushers, dredges, conveying machinery of certain types and coal-cutting machines, and in fact any hot-rolled steel products where service conditions require a hard surface to resist abrasion, would be improved if made of molybdenum steel, case-carburized and quenched.

J. D. CUTTER:—I think that Mr. Dawe did not intend to convey the idea that this merit-index formula could be used as an absolute standard of merit to be applied to comparing any two sets of tests without regard to the conditions under which the tests were made. Mr. Nelson called attention to the fact that the results cited at the top of Table 2 would be preferred to those at the top of Table 5, though the merit index of the former is lower than that of the latter. I think that all will agree with him in that statement. The tests in Table 5 were made on 2-in. square sections and those in Table 2 on ⅞-in. sections. The merit index cannot be used to compare sets of tests made under such dissimilar conditions. However, it offers figures that are useful in comparing different steels when broad averages are taken. I believe that in the average curves presented by Mr. Dawe in Fig. 1 of his paper, the sections are all average and the drawing temperatures averaged in the curves in Fig. 2, so the curves have much merit as a basis of comparison.

So far as my experience goes, calcium molybdenate can be used in the manufacture of molybdenum steel with as good results as with ferromolybdenum. I think that no steel using calcium molybdenate has been made in the last 18 months.

MR. SHERRY:—I think if Mr. Dawe would add to his paper the Brinell-hardness numbers that he obtained with these individual tests, they would be of considerable value. We found there was considerable variation in the Brinell hardness.

MR. DAWE:—The average Brinell hardness for each set of tests is appended herewith, the table numbers corresponding, respectively, with those given in the paper.

AVERAGE BRINELL-HARDNESS VALUES

Grade of Steel	Table 2	Table 3	Table 4	Table 5
Chrome Molybdenum	349	336	343	288
Chrome Vanadium	335	324	307	286
Chrome	294	291	281	256
Chrome Nickel	286	281	284	256
Chrome Molybdenum	299	277	295	281
Chrome Vanadium	294	289	302	289
Chrome	258	243	242	220
Chrome Nickel	270	254	255	220
Chrome Molybdenum	262	244	247	263
Chrome Vanadium	283	236	268	259
Chrome	229	238	229	207
Chrome Nickel	233	234	229	209

DEVELOPING A METHOD FOR TESTING BRAKE-LININGS

BY S. VON AMMON

As a result of the general policy of the Motor Transport Corps to standardize the materials used for automotive vehicles for Army Service, in cooperation with the Bureau of Standards, the Society of Automotive Engineers and the automotive industry, the Bureau of Standards has been engaged for some time in developing a standard method for testing brake-linings. While the work is not completed, much information has been gained. This paper reports the progress of the work.

The equipment developed and the methods used for both main and supplementary tests are described. Information is given regarding the coefficient of friction, as influenced by various factors. The endurance test, showing the comparative behavior of linings under conditions similar to those of severe service, is believed to be satisfactory as developed. Further work is necessary before recommending the conditions for the other test, intended to determine the relative endurance under ordinary or light service. In work done so far with a cooled drum and over a very wide range of power absorption and speed, difficulties arising from the accumulation in the lining of particles of steel cut from the drum have persisted. Supplementary tests covering the tendency of a lining to stick when brakes are left applied on a hot drum, and to ascertain the relative absorption of oil and water, are described. The influence of oil and water on the coefficient of friction is shown.—[Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

A. M. WOLF:—Will Mr. von Ammon state what was observed in regard to the brake-drums insofar as abrasion and distortion are concerned? Was the condition of the drum surface the same at the beginning of each test? There is no doubt that a difference might result in the life of a brake, depending on the type and material of the drum. The ordinary soft-steel stamped drum would be at a disadvantage compared with some of the machined drop-forged types.

S. VON AMMON:—The drum was ground after each test to establish a smooth working surface for the next test. It is believed that the type and material of the drum may have a marked influence on the life of the lining; and, to make results comparable, the drums used should be closely similar. This consideration led to the adoption of the standard low-carbon-steel drum used. It is planned to investigate later the influence of the drum material.

We have not been able to investigate the quality of

asbestos or impregnating compounds. It has been necessary so far to confine our work to developing the method of testing.

Any operator, using for the first time a new type of apparatus, is apt to encounter difficulties. The following suggestions may prove helpful in anticipating them. To reduce vibration the brake-drum should run true and its surface should be smooth. Before using a new drum the scale should be removed and after each test the drum should be ground to remove any deposit and to provide a smooth surface for the next test. This grinding we have done by hand with a piece of carborundum, using proper precautions. The samples should be mounted in their proper positions in the flexible steel shoes, and have good contact.

To reduce as much as possible the influence of uneven mounting of the sample on the wear factor, we subjected the samples to an initial pressure while the drum was stationary by applying a 150-lb. tension between the pressure-arms. This was measured by a spring-balance. After a few minutes this pressure was released; then a 50-lb. pressure was applied. The distance C between the marks on the pressure-arms was measured and, after again releasing the pressure, the test began. Other measurements of C were made after each stop, the pressure during the run being entirely released and then increased again to 50 lb. The daily test was discontinued when, near the regular stopping time, a wear of $C_1 - C_2 = 1.25$ in., or approximately that, indicated. To secure accurate data on the minimum value of the coefficient of friction, readings should be taken at least every 5 min. during the early part of the run. Later, when variations are small and operation is smooth, readings at 10-min. intervals are usually sufficient. It is well to check the spring-balance occasionally and, when the wear of the pinion and rack affects the readings, to replace them by spares, which may be obtained from the maker.

As a few machines were built with torque-arms 35 in. in length in accordance with the Bureau's first equipment, as against the later 28-in. arm, it may be well to point out that, for 6 hp. at 600 r.p.m., the force acting at the end of the torque-arm designated by W in the paper should be 18 lb. for a 35-in. arm and 22.5 lb. for a 28-in. arm.

The reduced heat capacity of a much worn drum tends to shorten materially the life of the lining and it is therefore recommended that a test drum be discarded when the rim has been worn to two-thirds its original thickness, and preferably sooner.

MANUFACTURE AND APPLICATION OF AUTOMOBILE VARNISHES AND PAINTS

BY L. VALENTINE PULSIFER

DIVIDING the ability of an automobile finish to remain new into the elements of proper quality of the materials, engineering of application systems, methods of application and care of the finish, the author states that the responsibility for them rests jointly upon the manufacturer of the varnishes and paints, the builder of the automobile and the owner of the finished product. Five basic materials that are necessary in automobile painting are specified and discussed.

Engineering systems of application and the actual methods of application are treated in some detail, inclusive of drying, and of surfacing or rubbing. The care of the finish is important and the precautions necessary in this regard are outlined. The paper deals with the application and not the manufacture of the different varnishes and paints that are mentioned. —[Printed in the January, 1922, issue of THE JOURNAL.]

THE DISCUSSION

L. V. PULSIFER:—I will supplement my paper by presenting some additional data on the materials used in varnish manufacture, the engineering of an automobile painting system and methods of paint and varnish application.

To many persons not conversant with the details of scientific varnish manufacture the purchase of a barrel of oil, a case of gum, a keg or two of driers and a drum of spirits of turpentine or turpentine substitute and their haphazard combination in a copper kettle probably constitute their idea of how varnish is made. The condition indicated existed in the old days when the itinerant varnish-maker went from one carriage-shop to another with his little stock of materials and primitive apparatus and made several months' stock of varnish on the job.

As an illustration of how the industry has progressed from its primitive beginning, I will discuss three sets of materials.

The first set includes typical driers and thinners: namely, litharge, red lead, cobalt acetate and manganese borate, compounds of the three metals commonly used as driers or catalyzers for oleo-resinous varnishes; also, redistilled spirits of turpentine and a highly refined special fraction of volatile mineral hydrocarbon used at times in conjunction with spirits of turpentine to obtain differing rates of thinner evaporation.

The second set includes six typical gum resins that are used in varnish manufacture. These range from Batavia Damar, that is used in making varnish which, in conjunction with zinc oxide, produces the whitest of interior enamels, to Egyptian asphaltum, the highest grade of asphaltum in use in the manufacture of various types of black japans. Other typical examples are Zanzibar gum which 50 to 75 years ago was the standard for high-grade varnish, Kauri gum, black Kauri gum and Congo gum, the last being a fossil resin from the region of the Congo in Africa.

The third set includes eight examples. First comes the flaxseed as it reaches the oil refiner; before dirt, straw, foreign seeds and the like have been removed. The second is the raw linseed-oil as it reaches the varnish manufacturer, still cloudy from suspended "foots." The third stage is the same raw oil after it has been settled clear in aging tanks, a process requiring several months. This settled oil is then refined by using either acids or alkalis, depending upon what use is to be made of the oil. Fourth comes the refined oil. The refining process is necessary to remove the "break," such as the mucilaginous matter and various earth salts, that would otherwise become separated when the oil was heated for conversion into varnish oil. The fifth step in the process is this refined oil after it has been bleached by rapidly heating it to about 560 deg. fahr. After other impurities have been removed by chilling the oil to 20 deg. fahr. it is known as bleached oil. The oil is bodied by again

heating it to about 560 deg. fahr. and holding it at that temperature for from 5 to 6 hr. The oil has then about the viscosity of chemically pure glycerine, and is ready to be made into varnish. A quicker and cheaper process of bodying the oil, by blowing air through it while hot but using a much lower temperature than 560 deg. fahr., produces what is known as "blown oil." While this process saves time and cuts down the "cooking loss" on the oil to almost nothing, its use in varnishes tends to cause premature deadening or dulling. The final step of the process gives the completed wearing body varnish, the time consumed in its production from the arrival of the raw linseed-oil at the plant to the final testing of the finished product averaging at least a year. When it is considered that the oil is tested in the laboratory, both chemically and physically, on its arrival at the plant and at each subsequent stage of its treatment, the above outline will indicate the work necessary to be done on only one of the raw materials entering into the production of high-grade varnish.

The importance of the above procedure was illustrated in a panel finished with two body varnishes identical in formula, process and material, with the single exception that one contained an oil properly refined and treated and the other an oil refined in such a manner that the flowing qualities of the oil were destroyed. This panel was finished in a vertical position by working and brushing these two varnishes in exactly the same manner and finishing with a horizontal brush-stroke. The varnish made with the properly treated oil flowed out to a smooth even surface; but the other varnish presented a series of bad "sags" or "curtains" and in places showed signs of "silking."

A painting system can bring out inherent defects of engineering by showing the relations of the elasticity of the various coats to each other and to the completed system.

In Figs. 1 and 2 each coat is represented by a horizontal line and the elasticities of the various materials by the length of the lines. The ends of these lines are connected by a line representing the "elasticity curve" of the system. The curve should be a smooth one as is brought out in Fig. 1, which shows that one should start with the primer and build *down* in elasticity to the flat color, and, starting at the flat color, build *up* gradually in elasticity to the finishing coat. If the materials are right, such an elasticity curve will indicate the durability and safety of the completed job.

Fig. 2 shows a system where the engineering was not properly done and was an actual case that we investigated. The layout was plotted approximately from the system in use. There was a good primer, the "half-and-half" and roughstuff were right, but the combination used for the flat color was too elastic; it was much more elastic than any of the rubbing coats that followed. Ordinary japan color was used and to it was added a considerable amount of an elastic sealer as a binder. This sealer was a material of high elasticity and enough of it was added to the flat color to make the flat color two or three times as elastic as the subsequent coats of rubbing varnish. The result was that the system pulled apart, due to the too elastic intermediate material. The finishing coat was torn and went to pieces in about one-third the normal time that would have been required if the flat color coat had been of proper elasticity. With a "sandwich" of that sort, an elastic coat between two brittle ones, one can upset the curve anywhere and cause trouble. If the rubbing coats are reversed, placing the least elastic one on top, trouble is sure to appear in the

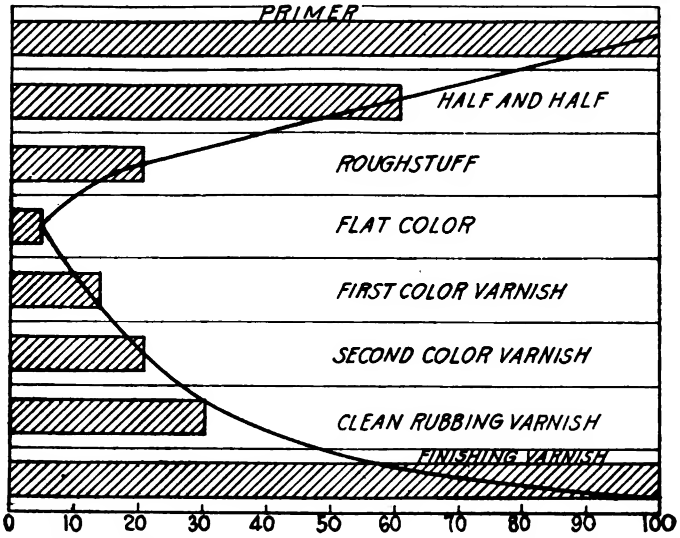


FIG. 1—PROPER CORELATION OF ELASTICITY IN THE VARIOUS COATS IS SHOWN IN THIS INSTANCE

premature breakdown of the finish. Figs. 1 and 2 show a study of the engineering layout of a foolproof painting system and the proper information as to the elasticity of the various coats.

The third subject is one of considerable importance at present: namely, the comparative results obtained by brushing on and by flow-coating the rubbing and finishing coats. To compare results and show in figures exactly what takes place in the application of varnish by these two methods, the four glass panels shown in Fig. 3, each 2 ft. square, were prepared. Two of these panels were varnished with automobile rubbing-varnish; one by flow-coating the rubbing varnish on, and the other by brushing, by a good brush-hand. The other two panels were varnished with wearing body-varnish; one by flow-coating and the other by brushing. Glass panels were used in order to measure the thickness of the dried varnish film, which was done in the following manner. A small cut was made in the varnish, going through to the surface of the glass underneath. The panel was then placed under a microscope, using a lens magnifying about 500 diameters. First, the surface of the varnish and then the surface of the glass were brought into focus. The difference between these two positions, read on the

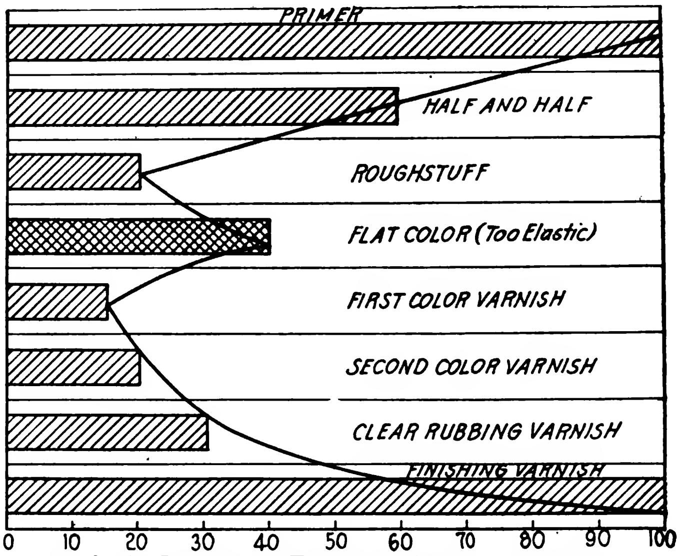


FIG. 2—AN INCORRECTLY ENGINEERED SYSTEM OF AUTOMOBILE PAINTING

micrometer adjustment of the microscope, gave the thickness of the varnish film at that particular point in microms. When it is remembered that 25 microms are equal to 0.001 in., the following figures read from the four glass panels will be readily understood. The figures for the upper left-hand panel in Fig. 3, on which the rubbing varnish was flow-coated, are as follows: The thickness at ½ in. from the top edge was 18 microms. About 3 in. from the top a series of thickness measurements across the panel ran 22, 23, 23 and 23; the middle of the panel gave values of 41 and 38; 3 in. from the bottom showed 53, 54 and 52; and the bottom showed 56 microms. In other words, the rubbing varnish at the bottom was practically three times as thick as at the top. It was too thin at the top for proper rubbing and much too thick at the bottom for proper hardening. If two or three similar coats were flowed on and the panel were finished in the normal way, the finish would begin to "alligator" from the bottom of the panel up; great cracks would appear at the bottom where the rubbing varnish was too thick. Not only does the thickness vary but, when one section of a panel is backed up with black, marked vertical "silks" will show in the rubbing varnish when the latter is flow-coated on.

In the upper right-hand panel, in Fig. 3, the rubbing varnish was brushed-on by a good brush-hand and measurements similar to those that were obtained on the previous panel are given. In this case the thickness ½ in. from the top is 25 microms, or about 0.001 in., which is a fairly normal thickness for a rubbing varnish. At 3 in. down it was 24, 23, 31 and 27 microms. In the middle it showed 25 and 26 microms; 3 in. from the bottom it showed 35, 35 and 34; and at the bottom edge where the last cross-stroke of the brush took place it was 32 microms. This gives a difference of from 25 to 32 microms between the top and the bottom, as against the difference in the flowed-on coated panel of from 18 to 56 microms.

The same results were obtained with finishing varnish. The micrometer measurements of a wearing body varnish flowed-on to a duplicate set of panels to the two just described read as follows. The lower left-hand panel in Fig. 3 showed 19 microms at the top. That is much too thin for suitable durability of the finishing coat and, unfortunately, it comes at the place of the hardest wear. In other words, the top of the panel gets the strongest sunlight, the worst hand abrasion and the like. Under the flow-coat method the varnish is the thinnest at the top. At 3 in. down it showed, 28, 29 and 30; in the middle, 49 and 49; 3 in. from the bottom, 56, 56 and 58; and 62 microms at the bottom. The variation in the thickness of film is from 19 to 62 microms.

The lower right-hand panel in Fig. 3, on which the wearing body varnish was brushed-on, shows a measurement of 32 microms at the top. At 3 in. down, the readings are 34, 36 and 38; in the middle, the film thickness is 41 and 40; 3 in. from the bottom the measurements are 44, 43 and 42; and at the bottom of the panel, 44 microms. Here we have a variation of only 12 microms, the minimum at the top being 32 and the maximum at the bottom 44. In the case of the finishing varnish that was flow-coated on, there was a difference of 43 microms, or more than 200 per cent.

It is well known that a uniform film is highly essential to both appearance and durability. Other things being equal, the durability of the final coat of varnish varies almost directly with its thickness. In other words, up to a point where it is not too thick to harden properly, its durability would vary almost directly with its thickness. If it is one-half as thick as it should be, it will be only one-half as durable. The fullness of the finish at the top of the panel will also be far below par, as the finishing varnish would have only about 50 per cent of its normal thickness at that point.

I hope that what I have said will tend to start a more scientific study of some of the problems I have outlined, on the part of the automobile builders, and that it will lead to greater cooperation between the makers of automobile finishing materials and those who use them.

W. C. KARNS:—From my experience, I think that not enough time is given to the ground coats for drying. The color coat, which is generally japan color, usually is applied as a base coat and it invariably causes trouble with the coats that are applied afterward. By eliminating the japan color coat, which I find can be done by using for ground work practically the same colors as one uses for the finished job, a more durable and a more substantial job of painting is produced in the end. Is it considered practicable to do that? I have done it with good results and watched it very carefully. I deem the flat color coat a trouble coat in most painting.

MR. PULSIFER:—There is confusion of terms as to what the color coat is. Some people speak of flat color, others of japan color, others of body color and others use different names. It is impossible to eliminate the color coats for the reason that the color varnish, as a rule, does not cover solid; but, the fewer the number of flat color coats put on, the better it is and, if the ground work can be made to serve the purpose of completely coloring the body so that the next coat will be the color varnish, possible trouble that might be caused by piling on too many coats of so-called japan color or ground color will be eliminated. Some of the old painting systems called for a coat of ground color and two coats of japan color, the ground color sometimes being a color of similar nature but poorer quality, followed by two coats of the highest grade of japan color, and then by color varnish and a clear rubbing varnish. With most colors at present these color coats can be cut down to one or at most two, and it is highly desirable to put on as few of these brittle coats as possible. In fact, in automobile painting it is just as risky, if not more so, to put on too many coats as it is to use too few. Some of the mistakes made in the early days of automobile painting were caused by piling on too many coats. The painters who worked on an automobile body did not realize the severe vibrations and strains it must withstand, these being much greater than those on any coach, carriage or railway car. An excessive thickness of paint is a detriment rather than an advantage; therefore, the number of coats has been reduced gradually since the early days of automobile body building. That tendency has been increased also by the adoption of metal as a base on which to paint. Mr. Karns is right in stating that the japan color coat or body color coat can be a source of trouble if it is put on too thick, or if too many coats of it are used, or if a coat is used that is not of the proper elasticity to correspond with the others. The color coats need not, however, be "trouble coats" if used properly.

A japan color coat should be so thin and so porous that the first coat of color will strike right through the japan color and bind it to the surfacer coats underneath. One can put a japan black on a piece of glass, for instance, and when it is dry put a coat of rubbing varnish over the black. If the glass is turned over, one will see the varnish come right through the black. That is an ideal condition for a japan color coat. If that coat is made too dense, too thick or too elastic, in attempting to make the job

durable, the "elasticity-curve" system is upset, as was shown in Fig. 2. Also, too many coats of the same elasticity upset a system of painting. There should be an easy curve from start to finish, as was indicated in Fig. 1.

C. S. RICKER:—How does Mr. Pulsifer determine the elasticity of these coats? How can we get a more economical dull finish such as is being talked of by a number of advertising men at present? My experience is that it costs more to put on a dull finish that will last than it does to produce a high-gloss finish of equal durability. What effect does the time of drying have on the elasticity and the durability? We are all interested in getting work through the factory as rapidly as possible. The problem of using artificial heat to assist the drying and the question of the proper degree of humidity are things we would like to know more about.

MR. PULSIFER:—Mr. Ricker has brought up several points that touch on the present rather unsatisfactory state of the finishing of automobiles. One is that the scientific men of the various automotive organizations pay very little attention to the finish. They have made very little attempt to find out why certain things were true and why certain other things were not true. Perhaps that has been a fault of the varnish manufacturers also. With regard to how the elasticity of these various coats is determined, the elasticity of pigmented coats depends first upon the elasticity of the liquid in which they are ground and second upon the amount and sometimes the character of the pigment that is combined with the so-called "wetting." The elasticity of each material can be determined readily by determining the elasticity of the wetting itself, and then by figuring the amount of pigment that is added to it. The pigment decreases the elasticity of an enamel or color coat, and the elasticity varies with the type of varnish used as a grinding medium, or wetting. As to the clear rubbing and finishing coats, it is possible to determine and state in definite figures the elasticity of any varnish by an elasticity reduction test that I devised a number of years ago. During the war this elasticity reduction test was used by the Government to determine whether a varnish was elastic enough for airplane use. The old method was to put two or three coats of varnish on a panel, place it out in the weather and find out how long it lasted before it cracked. That method had two objections. A considerable amount of time was required and the results varied at least 100 per cent on account of the difference in the weather. It is possible now to take an unknown varnish and by cutting down its elasticity by the addition of "run" Kauri gum, which is gum that has been melted and reduced to a condition to make varnish, to put it through a definite bending test on metal after it is dry. After determining the amount of run Kauri gum that one must add to bring the sample to the breaking point when the metal panel coated with it is bent-double rapidly, one can figure how elastic it was at the start. This test can be made readily on any of the varnishes used in making these automobile painting materials. An engineer who is interested in finding out the elasticity of the various coats would request the varnish maker to have the wetting of the primer, the roughstuff and the color varnish furnished to him as a clear liquid on which to make these tests. He gets the finishing varnish in a clear form, of course, and can make that test very readily in any good service laboratory.

ARTIFICIAL-HEAT DRYING

Very often a car is designed and a plant is built before painting or varnishing is considered as to paint-shop equipment, materials or production schedule, which shows no realization of the problems that will be encountered. One of the problems is that of the use of heat to speed the drying process. Heat properly used is highly desirable and, under modern schedules of production, it is absolutely necessary. In the case of materials such as we have been describing we do not mean an actual baking when we mention heat. Actual baking is used only in the case of such materials as fender blacks where a temperature of 350 to 450 deg. fahr. is used. Those are materials that would never air-dry and therefore must be baked. With materials such as we have been talking about the term "forced drying" is used; this means to increase the speed of drying by the addition of heat to the process. The heat aids the chemical action of the absorption of the oxygen, of course, and the drying is consequently more rapid. To make a general rule, one should use less heat with each succeeding coat, from the primer to the last coat of rubbing. The heat for the primer should not run over 150 to 175 deg. fahr., and it should grade down to 110 to 125 deg. fahr. for the last coat of rubbing. This heat must be applied at a proper rate; the jobs must not be coated and rushed right into a hot oven. There must be the proper percentage of moisture in the oven to prevent too rapid evaporation of the thinner and consequent surface hardening. Too high or too fast a heat causes surface or case-hardening. The ideal method is to run the jobs into an oven at the room temperature and then gradually raise the heat to the proper point. When it comes to the final flowing coat of body varnish, there is little to be gained by using forced drying. In fact, the only thing it does is to dim the luster. The body varnish can be made to dry free from dust somewhat more rapidly by using a temperature over

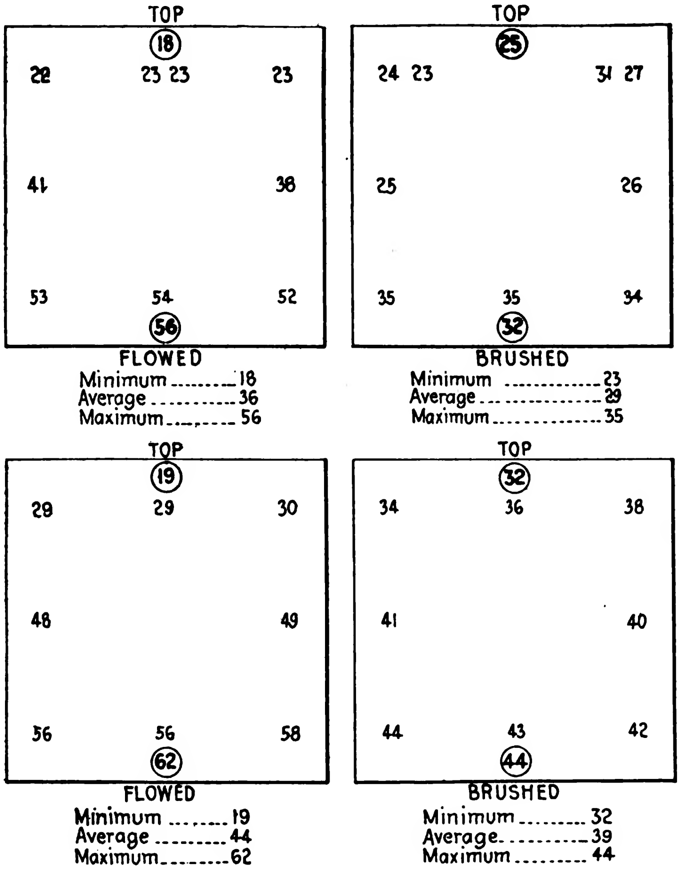


FIG. 3—THICKNESS OF COATS OF RUBBING VARNISH (AT THE TOP) AND (UNDERNEATH) WEARING BODY VARNISH WHEN FLOWED ON AND WHEN BRUSHED

100 deg. fahr., but the final hardening is scarcely assisted at all by forced drying. It is just about as dry 2 or 3 days after it is applied under good air-drying conditions as it would be if dried on the first day up to 110 or 120 deg. fahr. By heating it to that temperature one would get a thinner and less brilliant finish, on account of its great fluidity and the length of time that it remains in a fluid state after application to the body.

The subject of dull finish arises periodically. The desire for dull finish comes in waves and a wave seems to be at its crest now. There are two ways of producing a dull finish. One is to put so much pigment in the final coat that it dries flat. The particles of pigment stick up in the finish and cause it to have a flat appearance. The other method is to finish the car more or less in a normal way, and rub the final coat flat with pumice-stone flour and water. For durability, absence of spotting and good appearance the latter method is to be recommended. In that case a rather different type of varnish should be used on the body than is applied ordinarily. A varnish approaching more nearly in general nature to chassis varnish should be used for body finishing, because it takes a rub more quickly and better. Such varnishes can be made to have equal or greater durability than the body varnishes themselves, and their use avoids the common mistake of mixing rubbing varnish with the finishing when a job is to be rubbed flat. The method of putting enough pigment into the varnish results in a ready-made dull-finish but one that spots readily. This finish must be wiped off and polished continually with some sort of oil, to keep it looking well. Clear varnishes that will dry dull possess no durability.

Moisture Content of Wood[6]

Cornelius T. Myers:—For more than 2 years I have been engaged with one division of our industry in investigating the properties of wood; in particular, wood used in wheels. We discovered many things that seemed not to be recognized generally, even by those who make wood wheels. One thing was the protection of a wood wheel against moisture. It is essential to remember that wood changes its dimensions when it absorbs or gives up moisture. Wood is a hygroscopic material and, with a change in the atmospheric moisture, a change in the moisture-content of the wood takes place. Whenever the moisture-content increases, the dimensions of wood increase, to a very small extent and very slowly, it is true, but enough to affect its serviceability in time. There is very little increase along the grain of the wood, that is, in the direction in which the tree grows, but wood increases in a very substantial amount in the two other dimensions.

Wheels have been shipped by their manufacturers with what was called a coat of "primer." No one seemed to have any definite idea in regard to what a priming coat should be. When shippers were in a hurry, they shipped wheels without any primer at all. The man who got the wheels was just as much to blame as the man who sent them, because he often allowed them to remain in the rain or snow on the loading dock from 2 to 3 weeks. If the wheels were received in winter, he found that the moisture accumulated on the loading dock had swelled those wheels to such an extent that they had taken a permanent set. When they went into the warm factory and dried out, they became loose in the arch and in the felloe. Their usefulness was practically destroyed on account of the permanent set at the first swelling.

[6] This discussion is a combination of Mr. Myers' remarks at the Business and the Body-Engineering Sessions.

We conferred with the paint manufacturers to find out how they met this problem and what they had that actually would prevent the moisture from going into and coming out of wood; but they knew practically nothing about it, not even recognizing the matter as a problem. I believe that hardly a single paint manufacturer in the Country knew exactly what to do to wood to protect it against moisture.

We have conducted thousands of tests within the past year on various primers to ascertain how well they would protect wood. We outlined a test schedule and a number of paint manufacturers tried it out. After interviewing salesmen and others, including company officials, we let them test out what they said was the right paint. Invariably the regular products gave poor results when tested. One paint company tested three of its regular mixtures; one was very poor, another gave a better result and the third was still better. By modifying a few constituents this company then got results which were over five times as good as the previous average, insofar as moisture protection was concerned.

Then we turned to the Forest Products Laboratory, at Madison, Wis. Its representatives reported that they had investigated the subject at some length in connection with the protection of airplane propellers. When airplane propellers absorb moisture they do not always absorb it uniformly and become unbalanced. It was stated also that the absorption of a considerable amount of moisture by wood impairs its strength, which is a very important consideration. The Forest Products Laboratory has a great deal of information on wood, and is well equipped to make tests. Those interested agreed that this laboratory was a desirable place to carry on research work on wood preservation. There is a possibility of eliminating from 10 to 16 per cent of the $300,000,000 national paint bill per year. This applies not only to wheels, but to passenger-car and motor-truck bodies, body structures and frames. It includes also houses, floors, furniture and everything made of wood and subject to exposure to moisture. Better service can be secured from wood that is protected properly. I offer a resolution to the effect that the subject of wood-preservation research be brought before the Council of the Society and that the Society take action concerning it. The matter involves the conservation of our timber supply. It also opens up fields for the use of wood beyond any conception we have at present, airplane construction included. [The resolution offered by Mr. Myers was duly seconded, voted upon and carried.]

Mr. Pulsifer:—During the war this subject of moisture absorption through various types of paint and varnish films was deemed very important, especially by the Navy in its work in the construction of seaplanes. It was found that the hulls of seaplanes when exposed for a comparatively short time to rain or seawater sometimes became so water-logged that they could not fly due to the increased weight. Therefore, a series of experiments was conducted at the Forest Products Laboratory on the moisture absorption through various types of paint and varnish films. The Navy also took up the matter with the company I represent. I spent almost 2 years in research work on the absorption and dissemination of moisture through various types of paint and varnish films. We have records covering hundreds of experiments along those lines, and I would be very glad to have Mr. Myers see them. They proved that, with similar types of paint, one could obtain differences in both absorption and dissemination up to 400 and 500 per cent. The best kinds of material to keep moisture out,

or keep it in, under various conditions, were investigated carefully and the results of this research work were turned over to the aircraft division of the Navy. I presume that anyone interested in the shrinkage or expansion of wood can have access to this information.

Some wheels are shipped with no surfacing; others are shipped with a coat of what might be called a primer; but, in most cases, the latter is about as waterproof as flour paste. The automobile builder who thinks at all of finish apparently thinks last of the finish of the wheels, and the poorest material is put on the wheels. No attempt is made to get undercoats that are elastic enough to stand up without cracking or flaking around the joints, or varnish that is waterproof enough to prevent the rapid penetration or dissemination of moisture into and out of the wood. Mr. Myers apparently did not consider the varnish manufacturers as a possible source of information in this investigation. He may have been barking up the wrong tree. Much information is already available along those lines.

P. W. Steinbeck:—What would the effect be on the finished job of using different makes of material, such as the primer, roughstuff, varnish and finishing varnish, for each individual coat?

Mr. Pulsifer:—The result might be a perfectly good job or a thoroughly bad one. A bad job can be produced when each material is right in itself but not suited to the others. Unless a firm has an engineering laboratory in which the various materials from the primer to finishing varnish can be tested, it is safer to rely upon some one manufacturer and get materials suited to one another. That is not the only way, but it is by far the safest way; otherwise the result might be either good or bad and no individual manufacturer could be held responsible. His material might be right and so might the materials of others, but they might be unsuited to one another.

Mr. Ricker:—Did Mr. Pulsifer say that the body primer is not waterproof and will not protect the metal from rusting?

Mr. Pulsifer:—That is the reverse of the condition that ought to exist. The porous and non-waterproof coat of the system should be the flat color. It is essential to have the primer not only tough and elastic but as waterproof as possible, especially where jobs are sometimes primed and allowed to stand for a considerable time in the priming coat. That is true, not only of wood wheels, but of metal bodies.

A Member:—Are the results obtained by spraying varnish the same as those obtained by flow-coating? If not, can spraying be done satisfactorily?

Mr. Pulsifer:—To my knowledge the spraying of color and finishing varnishes has never been done satisfactorily. There are certain objections to spraying. Undoubtedly one could spray a small panel and get a much more uniform coat than by flow-coating, but there is great difficulty in spraying a whole body with varnish. The spraying system, as a rule, is used in modern shops for every coat up to the color varnish. It is an excellent system for primers, roughstuff or surfaces and flat color. In fact, it is probably the best way to put those coats on. A man skilled with a spray gun probably can get fully as uniform a coat with a spray as the best brush-hand can with a brush, and all brush marks are eliminated. With the color and the finishing varnishes the spray has been frequently tried but without success. It may be used in what might be called a semi-gloss color-varnish that dries almost flat, but the results do not appear to be satisfactory with a real color-varnish. The best method of applying the real color-varnish, clear-rubbing and finishing-varnish coats is by using a skilled brush-hand.

Mr. Karns:—Would you advise the use of more than one coat of clear rubbing?

Mr. Pulsifer:—In many shops one coat of clear rubbing-varnish would be an advance in the art. As a rule, the use of more than one coat of clear rubbing-varnish is not advisable. The last coat of color varnish may be what is commonly called a tint coat, containing very little of the color, and followed by a coat of clear rubbing-varnish, although in the case of some delicate tints, some color often is carried into the last rubbing coat. Blue has been mentioned as a popular color. It always is desirable to have a coat of clear rubbing-varnish on top of the blue, because blue is more chemically active with the varnish in the presence of moisture than almost any other color. If a coat of clear rubbing-varnish were put on top of the last blue coat, an appreciable increase in the durability of the finish would result, but with most colors it is not advisable even to consider more than one coat of clear rubbing-varnish. Two coats of color varnish, then two coats of clear rubbing-varnish, would build up to excess the brittle-varnish end of the painting system.

Chairman E. G. Budd:—Would the same type of primer be used on aluminum-finished bodies as on steel?

Mr. Pulsifer:—The same type can be used on aluminum and steel, but it is not a safe rule to say that it should be used always. It is not advisable to put a primer containing white lead as a pigment or as a hardener on aluminum. If white lead is in direct contact with metallic aluminum, rapid destruction of the aluminum will occur around moldings and the like, where the paint films become split and the moisture gets in. The primer coat for aluminum should not contain white lead. With that reservation, there is no reason the same type of primer should not be used on aluminum as on steel.

Chairman Budd:—In the case of a steel body having substantial surfaces of solder, how would the same primer be affected by those two metals?

Mr. Pulsifer:—If the soldering acid is removed and the surface is clean, the same primer will do for both. On bodies having a bad dent that has been built-up with a mass of solder, the paint over that particular surface may crack, due to the different rates of expansion and contraction of the solder and the steel under changes of temperature. Their coefficients of expansion differ greatly.

Chairman Budd:—Is not the cleaning of the surface one of the most important questions in proper finishing?

Mr. Pulsifer:—Unless the surface of the metal is cleaned properly, one cannot obtain a good finish, no matter how excellent the quality of the materials or the layout of the system may be. The surfaces must be absolutely clean, free from grease, rust, soldering acid or moisture of any sort. During rush work especially many jobs fail because of greasy fingermarks on the panels before priming; acid that works out under the moldings and other places; and rushing rusty and improperly cleaned bodies from the storage sheds to the priming department. Proper cleaning is very important. The first coat of material must be put on a surface perfectly prepared to receive it; otherwise trouble surely will result.

Mr. Karns:—How can the surface of galvanized iron be prepared to permit a durable job of painting?

Mr. Pulsifer:—It is very difficult to paint galvanized iron but, if the surface is scrubbed thoroughly to remove

any acid and subsequently cleaned to remove any grease, there should be no difficulty in painting galvanized iron after a suitable primer has been applied. The usual difficulty with galvanized-iron painting is that the paint used will not cling to the galvanized iron. We have found that the same type of waterproof and elastic primer used successfully for ordinary automobile painting is very successful when used on galvanized iron, even for exterior buildings, provided the iron has been thoroughly scrubbed. The best acid remover is a good scrub with clean water. Benzol or something of that sort used afterward will remove the grease. Benzol is better than gasoline for washing all types of metal surface that are to be finished, because present-day gasoline contains a high percentage of material that does not evaporate readily. Benzol can be obtained at very little more expense than ordinary gasoline; it cleans more quickly and evaporates completely. Benzol is much more inflammable than gasoline and its one bad feature is that it increases the fire risk, which necessitates strict adherence to insurance regulations.

A MEMBER:—What system is recommended for painting light-tinted or gray jobs for export that remain boxed for months and then are opened and probably handled improperly? We have had considerable trouble due to discoloration, especially with grays, on portions of the body such as the hood and doors. These discolored in different degrees.

MR. PULSIFER:—If kept in the dark, any of the varnishes that are based on fixed vegetable oils will turn yellow to a certain extent and sometimes to a very great extent. The result is that a gray job, although finished in accordance with the very best practice, will turn yellow when put in the dark. It will turn yellow to a degree determined by the thickness of the last coat of clear varnish on top of the gray. With such a panel as that exhibited in the upper left-hand portion of Fig. 3, where the varnish is 18 microms thick at one end and 56 microms thick at the other, after the panel had been shut up in a crate for a number of months the discoloration would start almost with the original color of gray at the top, where the varnish was thin, and grade down nearly to a golden brown at the bottom, where the varnish was thickest. There is no way of avoiding this discoloration if the paint is to be kept in the dark. The only way I know of to avoid discoloration, which probably would be all right for export use, is to put on a last coat of a finishing enamel of the desired gray rather than a clear varnish. That would result in a very thin film of varnish being on top of the gray pigment and minimize the discoloration greatly. It also would make the discoloration uniform, because the same amount of varnish would be on top of the pigment over the entire surface of the work. I know of no other way to avoid discoloration except to store the painted bodies in the light; this, unfortunately, is not practicable in the case of automobiles crated for export and stored for any length of time. A gray enamel finish would help to remedy this condition materially.

MR. RICKER:—Is the discoloration of gray and blue the result of chemical action between the colored pigment and the varnish, or of the effect of light passing through different thicknesses of varnish?

MR. PULSIFER:—The fading of blue color is due to the fact that under the actinic rays of sunlight blue coloring matter is not as permanent as some other colors. The destruction of the finish over the blue is due to the chemical action of the blue pigment itself with the oils of the varnish; this causes the oils to harden and the varnish to become brittle. Probably many of us have seen work that perished in a very short time where a heavy percentage of blue was carried into the last coat of color varnish and then a thin coat of finishing varnish was flowed-on or brushed-on by one of the high-speed finishers. The blue pigment seemed to eat the varnish up, and that is exactly what it did. It is the same thing that would happen if the varnish were dropped into caustic soda. The blues we have been getting recently have been much less pure than those we were able to get before the war. They have not been washed so carefully and as a result contain various impurities. Everyone has met with the same trouble. The only safeguard is to bury that blue under a coat of clear rubbing-varnish before the finishing varnish is applied.

Gray pigment should have no destructive effect on the varnish except that, other things being equal, varnish will last longer over a dark color than over a light one. The reason is that the destruction of varnish is caused partly by the same chemical or actinic rays that I spoke of in connection with the fading of blue. When the varnish is over black or a very dark color, most of these rays are absorbed after passing through the varnish; but when varnish is over white or a very light color, part of these destructive rays are reflected back through the varnish. The result is that the clear varnish gets it coming and going and, for that reason, other things being equal, a finishing varnish will wear longer over a black surface than over a white one. Of course, the black surface becomes hotter than the white, but the heat developed is not enough to harm the varnish. It is the chemical rays, which are heatless, that destroy the varnish.

BODY SEATING-DIMENSIONS

BY GEORGE E. GODDARD

THE dimensions of automobile-body seats receive consideration with regard to the features that are conducive to comfort. A diagram is presented upon which the dimensions treated are indicated, and a tabulation of seat dimensions of 12 representative cars is included.

Comments are made upon the factors influencing seat dimensions, as well as recommendations regarding the different desirable dimensions. The considerations are inclusive of cushion height, depth and slope, leg-room and head-room, upholstery shape and softness of trimming, foot-rest and other control-element locations, factors influencing entrance and egress provisions, seat widths and advisable front and rear-compartment heights.

The author recommends the standardization of a range of locations for the different control elements.
[Printed in the February, 1922, issue of THE JOURNAL.]

THE DISCUSSION

J. E. SCHIPPER:—The point that Mr. Goddard brought out about entering and leaving on the wheel side of the car is very important. He gives the distance between the steering-wheel and the left corner of the front-seat support as 9 in. I had occasion to measure a number of cars 4 or 5 years ago in which that dimension was as little as 7 in.; in many it was as much as 12 in. and on one car it was 14 in. It is an important dimension, particularly if a man has a passenger on his right side and

must enter and leave the car often. I know of one case where the spare tire, which was carried on the left side, prevented the full opening of the left front-door. Because of the small space and the restriction of the door opening, it practically was impossible to enter and leave the car on the left side.

In locating the controls, attention ought to be given to the position of the starting-switch pedal. In entering the left side of the car that pedal sometimes is accidentally stepped on, producing bad results when the engine is idling. Those two points are essential. Adequate hip-room is becoming more and more important also.

G. W. KERR:—In the front compartment, it is desirable to make sure that the operator has room to remove his foot from the clutch and place it on the toe-board. In some high-class cars there is practically no place for the operator's feet except on the pedal and the accelerator button. That is largely governed by the width of the dash and the arrangement of the lining of the inside of the cowl. The 2-in. slant of the seat stools seems to me rather under present practice and less than what is desirable. The general dimensions given by Mr. Goddard check very closely with what I believe to be proper measurements. I allow 7 in. under the steering-wheel to the top of the front cushion, grading the springs in the front cushion so that they will collapse to one-half of their ordinary length. That probably would let the passenger or driver sit at about the same height as is covered by Mr. Goddard's measurement.

The idea of using a standard-sized manikin as an aid to design is a good one but, rather than use one of average dimensions, I think the proper ones would be those of a man somewhat larger than the average, say 5 ft. 10 in. high. It has been found in the salesroom that, to insure the greatest amount of sales, the largest number of people must be accommodated. If average dimensions are used, anyone who is large will feel more or less uncomfortable, but there are ways of providing comfort for persons under the average size by changing the upholstery, placing extra cushions at the back and means of that kind.

G. C. BAKER:—We had an interesting experience some time ago. We found the manikin was too large, because it was not relaxed as the human body would be. I think it would be better to make it under rather than over the average size.

G. E. GODDARD:—Body engineers who have made it a practice to use manikins should submit their suggestions to the Passenger-Car-Body Division of the Standards Committee. It is a subject that I think is rightfully within its scope of work. We all know of the manikin that is made of cardboard and has few joints, but the human body does not have so much range of action as the joints of a manikin allow. There should be some kind of stop on the joints. There is need for a discussion and study of what the length of these joints should be. Every body engineer realizes the value to be obtained from a standardized manikin. The benefit is not so much in the comfort of the seat as in the softness or comfortable movement of the body, and has to do with dimensions and proportions. The manikin cannot be used very well to determine the shape of the back, but the average dimensions of the different joints can be obtained. This would at least prevent some of the short cushion-depths and short leg-length distances to the pedal that are still very common. I hope we can decide whether it is practicable to have a standard manikin. I think this subject should be cleared up.

JOSEPH LEDWINKA:—We have correct dimensions and use manikins having an average height of 5 ft. 9 in. with stops on the joints. We know exactly the movements of the ankle and knee and whether they are comfortable. By the use of these manikins we find it very easy to determine the seating capacity. It may be worked out by anyone on a one-quarter or a one-half-sized scale and made so that it will fit the regular predetermined dimensions.

L. C. HILL:—The engineering division of the Air Service at McCook Field has established a standardized manikin aviator around which airplane fuselages have been designed very successfully. I understand that the proportions of this manikin were obtained by measuring many pilots very carefully and averaging the resulting dimensions. The Air Service might be consulted in this regard and the conclusions that it has reached studied carefully with profitable results.

CHAIRMAN E. G. BUDD:—I think we need several manikins, an extra long one for leg measurements and one somewhat undersize for some other lengths such as cushion heights. It is very uncomfortable for a woman to sit in a seat which would be comfortable for a man of average or slightly more than average height. We need a large manikin to determine the distance between the steering-wheel and the front seat and one wearing a hat to determine the proper vertical measurement. This is an interesting subject and well worth the careful study of engineers.

THE PAST, PRESENT AND FUTURE OF THE MOTOR-OMNIBUS

BY WALTER JACKSON

AFTER outlining motor-bus history and relating how the introduction of mechanical and electrical propulsion on rails relegated horse-buses to the background, the author states that electric-railway construction is at a standstill and that the present demand for additional transportation facilities is being met by motor-buses that often are operated by individuals; presents railway statistics and comparative comment on jitneys, cross-country motor-buses and supplementary motor-bus service by electric-railway companies; and mentions many influential factors concerning motor-bus utilization.

Future motor-bus considerations include discussions of fare rates and operating expenses. The author believes that a comparison of the true cost of electric-railway versus motor-bus service has been obscured by certain factors having nothing to do with the engineering aspects of the situation, and that the economic fields of these services will be determined by the coordination of all mass transportation under one management instead of permitting indiscriminate and destructive competition. [Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

C. M. MANLY:—The use of motor-buses in suburban development bears a very different relation to the transportation problem from that of the street car or tram-

way. The value of suburban property has heretofore been based largely on transportation facilities and property owners are keenly interested in the subject. With the advent of motor-buses and the decline of the electric railway, I believe there will be a radical change in the situation. With motor-bus transportation a person who has property in a suburb cannot be at all sure that the transportation facilities at a later time will be the same either in location or adequacy as they are at the time he buys. On the other hand, a railway in operation involves a fixed investment and gives the land a fixed value. An illustration of the difficulties attending a fixed transportation investment was afforded by the situation in Toledo last year, where the street railway company was able to run its cars across the State line and thus withdraw part of the equipment; but the fixed investment resulted later in the return of this equipment to service in Toledo. On the other hand, with the motor-bus it is possible to move the entire equipment. It should, therefore, be possible to interest capital more easily in transportation. But I believe it will be difficult to interest it in the development of land and that transportation facilities will cease to carry as much of the burden in connection with suburban land development as they have heretofore.

WALTER JACKSON:—I confirm Mr. Manly's remarks. In developing a suburban community, if additional motor-bus service is delegated by the existing transportation company to another company which is known to have a reputation and will not remove its service, we may feel assured that that motor-bus route will continue to serve a particular group of people. If, on the other hand, motor-bus service is rendered by a new organization, which gives no assurance that its service will remain a fixture, the fact that the bus route can be changed without removing any rails is worth serious consideration.

HERBERT CHASE:—Mr. Jackson said that the cost per seat-mile for electric railways is about one-half that for motor-buses. Were the capital investment and the upkeep of the right-of-way considered in both cases? Is there any inherent reason why motor-bus transportation should be more expensive than railway transportation? There must be some basic reason for differences as great as Mr. Jackson mentions. So far as the vehicle itself and its cost of upkeep are concerned, I fail to see why Mr. Jackson's statement is correct.

On what grounds does Mr. Jackson base the conclusion that it is hopeless to try to beat the electric railway in cities by the use of motor-buses? They are competing successfully and giving satisfactory transportation in some cities in which the electric railway has, for one reason or another, been forced to discontinue.

MR. JACKSON:—That is a most important question. The comparative costs have two grounds. I refer to a paper read by A. R. Fearnley, of the Sheffield Corporation Tramways, of England, in which a really classic comparison was made of the cost of both kinds of service by a man who is known as a great advocate of the motor-bus. However, I am not satisfied with quoting English figures alone. According to American statistics a one-man safety car seating 32 to 35 people has so much overload capacity that it can carry 60 people easily and be run for 18 to 20 cents per mile, but a corresponding motor-bus cannot be run for that amount. When I speak of the 2 to 1 ratio, I refer only to the operating expense. However, with a service where the car intervals are only 10 min. and the vehicle seats 24 to 32 people, the investment for an electric railway would be so large as to make the cost of the street-car greater than that of the motor-bus. It is dependent upon the density of traffic. In a series of studies for the Boston Elevated Railway I recommended the adoption of the motor-bus for four or five localities where the company had track at that time. I pointed out that the cost of renewing and replacing that track was great and that, because the number of car-miles per year was not more than 50,000, new track and paving would not pay. On the other hand, I showed that if the company ran 500,000 car-miles per annum over the same track, the investment would be the same but the overhead charge so much less that motor-buses, at the existing costs, could not be considered.

The statement which Mr. Chase has made as to the replacement of trolley lines in some cities is true. I have said that some companies are trying to carry too many burdens of the past. They want a rate of return on a worthless valuation, and that necessitates a rate of fare that can be met by the motor-bus. That might be true of cities of 25,000 to 50,000 population, but we must consider each case individually.

TRACKLESS TROLLEY-CAR

L. C. MARBURG:—Who has had experience with the trackless trolley-car? I think it has been used to a limited degree for 15 to 20 years. It never has had a broad application, although recently I have read of a few additional instances where it has been installed.

A. J. SCAIFE:—One objection to the trackless trolley-car is that it is confined to a fixed route. One advantage of motor-bus transportation in large cities is that, if there should be something blocking the highway, the traffic is not held up but can seek other routes. It has been stated that it is not practicable in large cities to have street-cars run in the center of highways. Present laws stop all vehicles at the rear of a street-car while it is taking on or discharging passengers; thus in some instances from 10 to 30 vehicles are halted behind a car. With present-day congestion this is one of the greatest problems of mass transportation.

G. A. GREEN:—From my viewpoint, the trackless trolley-car lacks altogether the flexibility of the bus. It costs as much to build, its weight is as great and it possesses no advantages from the standpoint of acceleration or increased average speed. The cost of the necessary overhead structure ranges from $6,000 to $10,000 per mile; so that the cost of every route-mile operated is approximately equal to the cost of a completely equipped bus. Since the cost of the trackless trolley-car without the installation or maintenance of overhead structure or powerhouse equals that of the bus, the unit of investment cost is considerably in excess of that of the bus.

There are other serious disadvantages. Before trackless-trolley operation can be commenced, the overhead structure must be installed. If it becomes necessary to abandon a route, a large portion of this expenditure is lost. Likewise, extensions of routes cannot be effected promptly. Diversions on account of fires, parades, traffic blocks and the like are also impossible. Of course, a system of alternative routes is entirely out of the question.

The vehicles as a whole would be no cheaper to maintain. There is no reason to expect greater mileage from tires or decreased body maintenance. The electrical equipment is not more reliable than the conventional gasoline engine, clutch and transmission, and it does not seem likely that it will be cheaper to maintain. It must be remembered that the maintenance of motors, controllers and the like on steel rails is different from their

maintenance when vehicles travel over rough roadways. Certainly, the electrical equipment is not as well understood as the corresponding gasoline units. So, in the last analysis, about the only possible saving is in power. Here the question admittedly is open to argument but, in whichever way one regards the situation, the possibility of marked economy is not particularly alluring. If trackless-trolley operation is confined to points where power is extraordinarily cheap, the matter might well receive consideration; but, in my opinion, the disadvantages far outweigh the possible benefits.

It seems natural that the trackless trolley-car should receive attention from street-railway men, for they have been brought up to think in electrical terms. But, judging from such knowledge of these matters as I possess, I am of the opinion that one should never attempt to do anything electrically that can be done mechanically.

Chassis Lubrication

Cornelius T. Myers:—Mr. Green omitted upkeep expense in his recapitulation. The street-railway people are very much interested in the upkeep of these gasoline vehicles. The upkeep of those adapted more or less successfully to bus service has been pretty high. It is not safe to use a lower average rate of depreciation than 20 per cent per year.

In visiting service-stations and checking-up on repair costs, I find that a large portion of repairs is on the small parts about the chassis that never get lubrication. I have been working on chassis lubrication for about 10 years. I prepared statistics to show that operators of motor vehicles are justified in neglecting chassis lubrication. Considering 10,000,000 registered vehicles to be equipped with the devices now furnished by manufacturers for lubricating chassis parts, it would take a minimum of about 2 hr. per week per vehicle to give the chassis thorough lubrication. The minimum repair-charge for those vehicles would be $65,000,000 per year; the maximum, about $300,000,000; and a safe average probably somewhere between $100,000,000 and $150-000,000 per year. At 50 cents per hr. for 2 hr. per week per vehicle, $500,000,000 worth of someone's time is required. Hence, the public is absolutely justified in disregarding the lubrication of its chassis, many of which fail merely on account of the small chassis parts that are essential to the operation of the car. It is possible to lubricate those chassis. Their maintenance depends to a great extent upon lubrication at a minimum of 15 to 30 min. once in 2 months; that is, six times per year. With some 300 Class B trucks operating in one fleet in New York City, some remarkable records of repairs on chassis parts may be seen at the Army repair-service station. The cost has been exceedingly low. Certainly this is a field to be developed. If a minimum depreciation of 20 per cent per year in the chassis must be accepted, very few transportation companies will invest heavily in motor vehicles.

Mr. Green:—In my opinion Mr. Myers has placed undue emphasis on this question. The matter of proper lubrication is not a very difficult problem. It is largely a question of design. In our case we believe we have taken care of this matter satisfactorily. It is necessary to lubricate our vehicles but once in every 2000 miles of service, and the entire process requires about 15 min. The system is neither wasteful nor expensive. I think we can dismiss the question of lubrication as a controlling factor in the maintenance-costs of gasoline-propelled vehicles. This, of course, is on the assumption that the vehicle design is reasonably correct.

H. W. Slauson:—One subject, which possibly may seem outside the province of engineering but which will tend to make or break a motor-bus line, is the protection afforded by State legislation. Mr. Green probably would say that municipal competition is not serious, and we certainly hope it will not be. We see no reason why it should be serious, but there are instances in which a State has passed a well founded law in which bus rates are based on certain factors and these laws have been over-ridden by municipal and county legislation with the result that almost as many laws prevail in that State as there are counties. When a company is formed and money is invested in a bus line, there must be assurance that it will be protected from legislation as well as by it. It is unfair to an investor to face the competition offered by a municipal or county line which is not operated on the same basis so far as franchises, taxes and license fees are concerned. We are trying to overcome that by the uniformity of the vehicle law, but that is by no means perfect. It has failed in several instances. I believe this is one of the serious problems with which the motor-bus line is confronted.

Illumination

L. C. Porter:—I have been following with interest the development of motor-buses for the last 4 or 5 years, particularly in connection with the lighting, and have wondered at the lack of adequate illumination. Illumination has increased in trolley cars; in fact, in a number of cases, this has been required by public-utility commissions. I think the same requirement will apply to the motor-bus. I believe that the companies operating motor-buses would do well to forestall such legislation by supplying sufficient light. The original individually owned jitney bus was more or less unpopular, but as the motor-bus has developed and is now operated by competent companies on regular schedules, this opposition is gradually passing. Suitable lighting of buses would gain popular favor and be good advertising. A bus should not only be well lighted inside but carry illuminated signs visible from a distance to announce its route. It should also have adequate step lighting, and stop signals for the protection of those driving behind it.

Many buses have what are called dome lights. They are very inefficient, absorbing from 50 to 60 per cent of the light. With reflectors instead of domes, most of that light could be made useful. Why do the builders allow such low head-room in motor buses? If the roof were 1 ft. higher, the use of highly efficient reflectors would be possible and satisfactory lighting could be had with a small amount of electrical energy.

A Member:—I was one of the contenders for a motor-bus franchise in Chicago, but did not go through with the proposition because there are five different municipal bodies to contend with. After I had talked to these representatives, my opinion was that whoever secured that franchise would fail. The pioneer, who secured the franchise, failed within 3 years. I think the service has been continued for about 3 years since that time and that the company has recently been purchased by another organization for about 25 cents on the dollar. I feel that now with proper men, it would make a good investment.

On the South Side of Chicago, on Michigan Avenue, there are a number of viaducts. The municipal commission controlling Michigan Avenue insists that a certain route be covered to obtain a franchise. Can a six-wheel motor-vehicle of the trailer type be built with low enough head-room to afford the requisite passenger-carrying ca-

pacity? To secure that franchise virtually a new type of vehicle must be developed to make the route pay.

MR. GREEN:—From a motor-bus standpoint, a low center of gravity is highly desirable because the possibility of overturning is decreased and the stepless feature is of value in avoiding accidents in boarding and alighting. There is also an opportunity to shorten the time required by passengers to enter and leave. Assuming a correct suspension system, the riding properties are better. Decreased height lessens the liability to injury of persons seated on the upper deck. A low-hung vehicle also has a more graceful appearance. Such vehicles look safer and one must not lose sight of this from the rider's standpoint.

Regarding the question of lighting, I agree in general that the present situation leaves something to be desired. There is a tendency to demand better illumination. Much difficulty has been experienced in the past in obtaining generators of satisfactory capacity, but, as a result of experiments, our research department has made progress in this direction and within the coming year we expect to effect marked improvements. The problem of properly illuminating a bus is by no means simple. Each of our vehicles, completely equipped in accordance with our latest standards, requires 224 cp. This is beyond the capacity of the average generator in use on passenger cars.

MR. CHASE:—Is there an inherent difference in the cost of operation of a motor-bus and an electric street car, aside from the matter of size? It is evident that if a vehicle can carry twice as many passengers with the same crew, the operating expense will be reduced, but is there a difference in upkeep expense and with which is it the greater? Is it considered desirable by the majority of engineers to have a special type of chassis for buses, or is the conventional truck chassis, with certain minor body modifications, applicable?

H. C. MCBRAIR:—In one locality where a large number of motor-buses run from other communities into the city, an excessive tax has been levied on the motor-buses. The railroads are putting on motor cars to regain the trade that has been going to the motor-buses.

SPECIAL FEATURES OF BUS CHASSIS DESIGN

R. E. FIELDER:—As to whether it is necessary to have for motor-buses a different chassis from that used for truck work, I would say that human freight needs a definite amount of space and a bus body must be at least 7 ft. wide, to provide comfort for the passengers. The seats usually are along the side walls or arranged transversely; therefore, the supporting wheels and springs are placed on as wide a base as possible. In most cases it is desirable to have the width about 14 in. greater than that of the truck; otherwise the vehicle is unstable. Few steps should be used, particularly in cities where many people get on or off at one time and cannot see where to place their feet. Therefore, the vehicle floor should be as low as possible. The frame of a standard truck is about 36 to 40 in. above the ground. Since a passenger can step up only about 12 in., four steps are required for entrance to the body and they will stretch across the floor so that no platform space is left. These are some of the many features that require a bus to be of special design, and that make a truck chassis totally unsuitable for safety and fast passenger-bus operation.

OPERATING COSTS

MR. MARBURG:—As to any inherent difference between the cost of operating a motor-bus and that of a street-car, I think Mr. Jackson gave the answer when he said it is a question of traffic density. The cost of operating an electric railway consists of maintenance charges, the cost of the personnel necessary to operate the cars, the cost of electric current and fixed charges such as interest and depreciation. In the case of the motor-bus the place of electric current is taken by gasoline or oil. Some charges are proportional to the mileage; others are entirely or practically independent of it.

Taking first the variable charges, there hardly can be a doubt that cost of upkeep is considerably higher with the motor-bus than with the street-car; and, furthermore, it seems to me that the cost of gasoline and lubrication is also much higher than the cost of electric current, all charges being, of course, based on a seat-mile. On the other hand, fixed charges, consisting largely of interest and depreciation, are much smaller with the motor-bus than with the electric street-car, because the investment per seat-mile is much less with the former.

Since fixed charges must be distributed over the number of seat-miles operated, it is evident that the system with low fixed charges, that of the motor-bus, will have a total cost per seat-mile which is more or less constant; but with the system having high fixed charges, that of the street-car, the total cost per seat-mile decreases rapidly with increasing seat-mileage. The result is that the motor-bus operates more economically with low traffic density, and with high traffic density the street-car is cheaper.

MR. GREEN:—To attempt to analyze the difference in cost of operation between street-cars and motor-buses is a rather large undertaking. The street-car has one feature the bus has not; people can be packed into it. I am, of course, referring to "standees." It has an almost unlimited capacity for overloading; so, when discussing costs, one must consider whether reference is made to cost per passenger carried, or cost per seat-mile or cost per car-mile. Taking the cost per car-mile, in units of about the same seating capacity, the difference, I think, would be in favor of the motor-bus.

MR. MARBURG:—Are we not making an assumption that does not apply? The electric car always has a much greater seating capacity than the motor-bus.

MR. GREEN:—I think that statement is not altogether correct. Our single-deck bus seats 29 passengers; the double-deck bus, 51 passengers; the average New York street-car seats only 40 passengers.

CHAIRMAN B. B. BACHMAN:—Col. F. W. Perry, representing the Hon. Grover A. Whalen, commissioner of plant and structures of the City of New York, is present and we shall be glad to have him address the meeting.

MUNICIPAL OPERATION IN NEW YORK CITY

F. W. PERRY:—The Commissioner delegated me to address this technical meeting in his stead. Mr. Whalen is operating trolley lines, bus lines and trackless-trolley lines in the name of the municipality. The experience covers only about 2 years. The necessity for operation by the municipality has been due to a public emergency existing in New York City in the nature of no transportation if not public transportation. The trolley lines were wholly abandoned and the cars disposed of. The city took over the lines and put on the cars, took the people to church on Sundays, took the children to school and gave the business people a chance to reach the ferries and get to business. The bus lines took the place, by and large, of railways that had abandoned operation. These trackless-trolley lines are operating on Staten Island and extend existing transportation lines into the territories that need transportation. They are not for real-estate

development, but to fill the existing demand for riding. They extend existing transportation lines that could not be extended by the operating companies in view of their financial condition.

The whole question is complicated and cannot be disposed of easily. I think that no competition is involved in any of this transportation. During a serious strike in Brooklyn, when the railway companies were unable to operate, the Commissioner ran upward of 1000 buses over the routes and continued running them until the companies were able to pick up the load; but, in the meanwhile, the service was enjoined and had to be shut-down.

Mr. Jackson has a very well anchored idea that the buses ought to be operated by the existing utility companies. There are many who think that way. Keeping in mind what the utility companies are carrying in the way of financial loads, there is nothing special in what has been said, other than what Mr. Green mentioned a moment ago, about the comparative cost of trolleys and buses. It seems to me that a very much heavier load is being carried in the case of the trolley-car passenger-mile than in that of the bus. This largely increases the cost of electricity. While the platform cost might not differ, when the present-day cost of electricity per kilowatt-hour is taken into account, there is a difference which is against the trolley, and particularly the trolley of the large Pullman type.

N. G. SHIDLE:—Mr. Perry mentioned one point in Mr. Jackson's paper that perhaps is misinterpreted. I do not pretend to speak for Mr. Jackson on the matter of advocating that buses probably will be operated by the utility companies that are in business at present, but I believe that the difficulty is as follows: As I understand it, truck builders who perhaps believe that there is a wide motor-bus market are not certain just where that market is. We can talk as we will about the great future of the motor-bus, but when a company turns its plant over to the building of special motor-buses, it must know where the output can be sold.

It is interesting to study the development of the motor-bus in the places where it already has been developed, in order to learn how it can be developed in other localities. Mr. Jackson has made a detailed study of conditions in England. He found, I believe, that bus lines there have, to a large extent, been developed by transportation companies already in the business that had seen the possibilities of tying the motor-bus to their present transportation lines to make a better transportation system. The public-utility companies in England have started bus lines or added bus lines to their present equipment on that basis; and, to some extent, perhaps that is the basis of the idea that the utility companies at present in the United States are likely to be the ones which will promote the bus lines.

Mr. Perry said that he believed this matter of buses and trolleys is not one of competition, and I most heartily agree with him. Fundamentally, the motor-bus is a transportation unit. Just as it was found that the only way the motor truck could make progress was by selling it as a transportation unit and not as a motor truck, the motor-bus will take its place as a unit in our transportation system. If it is found to be a good transportation unit after proper tests and trials, it is bound to take its place. The matters of State legislation and municipal competition with privately owned bus lines, as has been mentioned, undoubtedly constitute most difficult problems confronting the development of the motor-bus; but, if in each particular case the bus proves that it can make money, it will be used, regardless of the attitude of the electric-railway people. When the public finds that the motor-bus can help it out, buses will be used. There are some cases in which the motor-bus is the most economical transportation unit, certain other cases in which the electric railway is the logical transportation unit and many intermediate cases. It will require a long time in the intermediate cases to determine which is the better. It will depend to a large extent upon the capital already invested in the enterprises and the returns being made on that money, rather than upon furnishing the most efficient transportation to the community. Eventually, efficient transportation will be furnished, whatever it shall be; the result will depend partly upon the possibility of developing the motor-bus mechanically with due regard for the comfort of passengers. The remark referring to the truck that carries freight and the bus that carries human beings as freight tells the whole story; there is a necessity for something different.

COLONEL PERRY:—I thought I made it clear that I was not indulging in optimism about any particular kind of transportation. I was merely stating what the City of New York is doing; it is running these buses, but not in competition. There is ruinous competition going on in other cities. I want to distinguish what is being done in New York City from what is being done elsewhere. We do not run jitneys to put trolley cars out of business. I hope everyone understands that. Anyone who has made a study of the question knows that if trolleys are too expensive, we would like to sell them and run buses.

MR. SCAIFE:—When the operating cost of the motor-bus is compared with that of the street-car, one should take into consideration the trackage cost, which, I understand, is from $40,000 to $60,000 per mile of double track, and that the safety car costs about $8,000 or $10,000. With the motor-bus, the investment is entirely in the rolling stock. So far as the operating cost of the street-car per seat mile is concerned, that cost is divided over the entire period because the overhead charges are fixed. With the motor-bus, that is not the case; trackage and trolley overhead does not have to be charged against the seat cost per mile.

With reference to the use of the motor truck as a motor-bus, I believe we are beginning to realize that it is impossible to use a motor-bus that is built on a motor-truck chassis. I believe the bus must compete with the comfort of the average street-car, with reference to lighting and riding. The jitney undoubtedly has injured the motor-bus in its pioneer work, where any kind of a body was put on a truck chassis and the job was called a bus; rough-riding, uncomfortable and poorly lighted. I believe that has done more to retard bus development than anything else. However, as Mr. Green stated, electric companies are making generators that will take care of bus lighting, and the bus builders are designing chassis that will have easy riding qualities.

With reference to legislation, years ago in New Zealand, I believe a franchise to operate a steam railroad was given provided the company would erect a fence along the entire right-of-way so that people would not become panic-stricken at seeing a train travel at the rapid rate of 20 m.p.h. As far as legislation is concerned, everything new must go through such a period of opposition.

J. E. HALE:—To the rider, the most important elements of adequate transportation are the maintenance of schedules, comfort in riding, safety and speed. There is a general reluctance to have street-cars in residential sections. I mention these things because the cost is not the only consideration. Factory workers, who must

watch their pennies, select the most economical means of transportation. Who can indicate whether a good, efficiently operated, motor-bus system can transport people from point to point more quickly than can a street-car system? That is a very important point. In many instances people take a jitney in preference to a street-car because the jitney will make the trip in less time.

Nearly all the electric street-car companies serve the public with electricity and power, the transportation department in many cases being financed to some extent in this way. If street-cars were removed and trolley transportation abandoned, what would the effect be on the light and power service the companies give the communities?

HARMONY IN CAR UPHOLSTERY

BY R. S. QUAINTANCE

TAKING the artist's viewpoint, the author discourses on the subjects of color, color harmony and the psychological effects of color, as a prelude to a discussion of how the decoration of car interiors can be made most effective, this being necessary because of the elusive quality of good taste, a quality of appraisal rather than one of creation, and because esthetic taste depends upon the degree of mental development of the individual, although possessed in some degree by all.

The primary, secondary and complementary colors are defined and their mode of selection is described preliminarily to a consideration of color values and the selection of the most effective color-schemes, application of these principles being made thereafter to the decoration of car interiors, inclusive of comments on the most suitable fabrics and patterns. The author believes that color will be considered eventually in the automotive industry as being on an equal plane with lines and form. [Printed in the February, 1922, issue of THE JOURNAL.]

THE DISCUSSION

A. J. NEERKEN:—What colors have the greatest popular appeal? In the quantity production of a medium-priced car, where only one color or one type of upholstery can be used, what color would please the greatest number of people, and what the second greatest number?

R. S. QUAINTANCE:—It has not been determined what color is the most popular. We must be guided by the color selected by the car builders. We have no means of determining which color would actually be the most popular with the purchasers of cars. Blue, probably, is the most popular; gray comes next.

CHAIRMAN E. G. BUDD:—Which color would show the more correct taste?

MR. QUAINTANCE: — Both show correct taste. One would not say, for instance, that red is a correct color for the interior of a car. Both blue and gray are suitable; blue, however, is a cold color. Gray is neutral; it is neither cold nor warm. Blue is extremely popular. I think brown is the most desirable color for a closed car, because it is one of the warmer colors.

MR. NEERKEN:—Is it not necessary to choose a more or less neutral color so that it will harmonize with what people wear? If one chooses a bright distinctive color, it will not appeal to many people.

MR. QUAINTANCE:—On the other hand, a neutral color is ultra-conservative. A blue color need not be disagreeable; in fact, it can be made agreeable very readily. We would not use a pronounced blue, which might affect certain personalities. Blue is the coldest of all colors, and some types of blue actually might be depressing. By mixing or toning the blue down to some of the warmer colors, one could effect an almost neutral color harmony by using blue as the dominant color; it would not, however, be an intense blue.

J. E. SCHIPPER:—Is there anything about the colors themselves that makes them more or less susceptible to fading, thereby causing unevenness in the appearance of the upholstery?

MR. QUAINTANCE:—Yes, some colors will fade. Blue will fade first. Tones of red come next. It is also very difficult to prevent green from fading. However, manufacturers today are able to produce fabrics that will not fade readily, but in time the sun will affect all shades of blue.

A MEMBER:—Is it not true that there is a manifest tendency toward the red-grays in upholstery? Gray is suitable as a background for harmonizing any body color. Red-gray is more permanent and is warmer.

MR. QUAINTANCE:—That is true; it will produce a very harmonious, interesting color scheme.

A MEMBER:—Is there not some rule to determine what the color of upholstery should be to harmonize with the body color outside?

MR. QUAINTANCE:—There is no fixed rule; a wide latitude is provided for body-color paint. Colors must be selected with a knowledge of their relationship to one another. If the dominant hue on the interior is on one side of the color circle, one is privileged to go 180 deg. on that circle to obtain a suitable color for the outside; or, one may use a color distinctly related to the interior.

A MEMBER:—Suppose one used a maroon color for the outside of the body, would it be safe as a rule to use gray for the inside? That would harmonize with the outside maroon color.

MR. QUAINTANCE:—That would be a safe rule, but one does not wish to limit the choice to that; there are other equally safe combinations.

A MEMBER:—Is not the tendency of the times more toward that type of decorating than toward any other?

MR. QUAINTANCE:—I have not noticed that there has been any fixed rule in regard to applying any particular color in preference to any other. My observation has been that there has been no great departure from a related color scheme between the exterior and the interior.

A MEMBER:—Is not the tendency always toward a gray, if possible, for the interior?

MR. QUAINTANCE:—Yes.

CHAIRMAN BUDD:—In regard to the point of emphasizing the interior by spots of color, how can that be done on the outside of the car?

MR. QUAINTANCE:—Most of the car exteriors are so conservative that I have not been concerned about them, but I think it would not be necessary to put spots of color on the exterior if the cars were painted some color other than black. The interior primarily exerts an influence upon the passenger and that influence may be either agreeable or disagreeable. In the case of conservative harmony schemes, we can eliminate much of the depress-

ing sameness that is to be sensed in some interiors by an occasional spot of complementary color.

CHAIRMAN BUDD:—Most cars start with black on the hood and fenders, and usually are black on the roof.

MR. QUAINTANCE:—Black is neutral and can be used with any color in the circle; the same thing is true of gray and white.

CHAIRMAN BUDD:—Would no body color that we might make clash with black?

MR. QUAINTANCE:—No, although one could use a strong contrast. White would be the strongest contrast, but white is not a color. Yellow would be the strongest contrast, but that would not be discordant.

G. W. KERR:—I think that the last paragraph of Mr. Quaintance's remarks about body color is hardly justified by the facts. From the beginning, automobiles have been painted practically all colors of the rainbow. The all-black car is the exception rather than the rule. Many production cars are painted blue and others are painted green. Other colors than these are and have been used continuously since the automobile came into use. I think he laid hardly enough stress upon the subject of making the upholstery match or harmonize with the paint that is selected for the outside of the car. There is a harmony of contrast and a harmony of matching. With a color like yellow, for instance, the best contrast would be blue. A color frequently is selected for the body of a car that has a complementary or best contrast color not in itself pretty or one that appeals to the eye. In a case like that, it is necessary to use some other part of the color circle that will provide harmony. Maroon is a color difficult to harmonize by contrast because its complementary lies in the greenish-yellows, which are very poor colors and not handsome; but it always is possible to harmonize with maroon by matching and using a material corresponding with it. Another important resource in harmonizing upholstery with exterior finishing is the use of the neutrals, white, black, gray, silver and gold. Silver and gold harmonize with anything; white and black are suitable for use with any color, and so are the grays usually. If harmony cannot be attained with a certain color, we may resort to a neutral and obtain a contrast of a slightly lower tone than is found by using the complementary.

G. J. MERCER:—Selecting fabrics from small samples of goods will at times be disappointing. That is to say, when the fabric is used to trim the interior of the car and a larger quantity is used, the appearance may be different from the impression one gets from the sample. Do any particular shades have that tendency more than others?

MR. QUAINTANCE:—Not that I have observed. I believe that possibility applies to all colors. On the other hand, a large piece of cloth will also be deceptive when draped as cloths generally are. The color that is synonymous to light will catch and reflect the light and produce on a large piece of cloth a sheen, a glow, which will be equally as deceptive as a small piece of cloth would be. It is necessary to use one's imagination largely when selecting fabrics. Trimming a sample job and then determining its value is a good plan that has been tried. That is one of the safest ways, although an expensive one, to determine whether a particular cloth will meet the needs of a particular company.

MR. MERCER:—One fabric manufacturer used to show all the laces, cloths and silks draped under conditions similar to those of the interior of a car. Is that method still followed?

MR. QUAINTANCE:—A number of car-fabric manufacturers will furnish, with the samples of the fabric, samples also of the laces, the seaming to be used, curtain silk, carpets, curtain cord and the like, but I do not believe they enable one to determine whether the cloth will be satisfactory after it is installed. They merely aid in visualizing in a measure the color harmony that is possible in the interior through the use of the different trimming accessories. Do you mean that some fabric manufacturers used to trim a model car?

MR. MERCER:—No, the materials were draped in a manner to give a good impression of the back and side, for instance.

MR. QUAINTANCE:—I have never seen that done. It is customary with my firm to show cloth draped over an arm. That will demonstrate how the cloth will tuck in on the plaits and corners, and enable one to get a conception of how it would look on the sides. I know of no one who provides an atmosphere that would enable a customer to judge correctly how the materials would look in tht interior of the car itself.

W. C. KARNS:—My experience has been that what appeals to one person does not appeal to another. Would you not deem it advisable to change the various fabrics to comply with the varieties of taste?

MR. QUAINTANCE:—Yes. One of the serious mistakes of merchandising lies in offering only one example of car interior to customers. In my opinion they should have a choice, because certain colors produce definite effects on certain personalities. For instance, the red colors are warm and the blue colors are cold. The red is stimulating and the blue is depressing. To a nervous, volatile type of person, a color on the warm side of the circle might be sufficiently stimulating to be really exciting. That person probably would feel at home and be more comfortable with a color scheme based on the warm side of the circle because of his nervous temperament. On the other hand, the phlegmatic type would probably prefer the blue side. But that side, if he only knew it, would produce a feeling of depression and be too soothing and quieting, although it might appeal to him more than the warm side. There is a definite personal feeling to be secured from colors and whether people are conscious of it or not, they respond to their influence. Almost everyone has sensed color, even though he has not been able to define his feeling of comfort or happiness in the presence of certain hues. Comfort or happiness or depression is the result of the proper or improper use of colors. A choice should be provided by the car builder because of this wide variety of personalities among customers.

CHARLES F. HOPEWELL:—The paper can be divided into two distinct sections, one relating to car-upholstery color-harmony and the other to upholstery materials. I agree fully with Mr. Quaintance's plea for better color-harmony. He states the fact that the less obvious the color element is, the more quality the different tones possess. He also states that tints and shades rather than pure colors should be used. One of the most effective means of obtaining this tone of color is the use of cut and uncut-pile mohair-plush. We are all familiar with this type of plush, as it is a standard in Pullman cars.

I disagree in regard to his conclusions as to woolen fabric being the best fabric to use for closed-car upholstery. However, Mr. Quaintance does state that mohairs woven from the hair of the angora goat are extremely serviceable, and he further states that velours give a rich, luxurious effect. The United States Department of Agriculture Bulletin states that mohair has a luster peculiarly its own. Therefore, does it not necessarily follow

that mohair plush is extremely serviceable and most luxurious? I think this alone should disprove Mr. Quaintance's contention for the use of various kinds of weaves of woolen cloths in preference to mohair plush.

Closed-car upholstery should possess durability, sanitary qualities and good appearance during the life of the car. In regard to the durability and sanitary qualities of mohair plush, let me recall to you the paper presented by Charles B. Dudley, who was for many years head chemist of the Pennsylvania Railroad, before the American Public Health Association. His conclusion, after exhaustive tests covering a period of more than a year on a variety of fabrics, was that from the standpoint of health a mohair-pile fabric is the only one that should be used. As regards durability, we know that they are used universally in railroad cars, as no other fabric has been found equal to mohair plush for wear.

The last few years have seen the development of mohair tapestry plush now being used on furniture that can be seen in the newer hotel lobbies. It has been adopted for both its appearance and wearing qualities. It is now available for car upholstery. Many fabrics possess, at the time of the sale of the car, all the requisites of appearance; yet none surpasses in appearance or possesses the wearing qualities of mohair plush with its pile fabrics.

We all know that it is impossible to keep oil, grease, dirt or tar-laden dust out of a car. Mr. Quaintance recommends the protection of the car upholstery by slip-covers, during the period in which the windows of the car are open. Such covers are absolutely necessary with woolen fabrics, but are not necessary with mohair plush. After a woolen, or non-pile, fabric has been spotted with oil or tar and dust, if we seek to remove the spot, say with gasoline, we do a poor job at the best, and the location of the spot becomes manifest as soon as the upholstery is again exposed to dust. This is not true with mohair-pile plush, as any spot that may exist is on the woven back of the plush and the pile face hides it entirely.

I do not say that there is no field for a woolen fabric for closed-car upholstery, for in many cases, where price governs quality, such a field exists. Where quality, durability and continuous good appearance govern, mohair plush is supreme for use as closed-car upholstery.

MANIFOLD VAPORIZATION AND EXHAUST-GAS TEMPERATURES

BY O. C. BERRY AND C. S. KEGERREIS

STATING that present internal-combustion engine fuel is too low in volatility for economical use and that this is the cause of engine-maintenance troubles, the authors believe that, since it is not possible to obtain the more volatile grades in sufficient quanitity, the only hope of remedying this condition is to learn how to use the heavy fuel, and that the most promising method of doing this lies in the effective use of heat.

As the experimental data regarding the best temperature at which to maintain the metal in a hot-spot manifold and the range of temperatures available in the exhaust gases, are meager, the authors experimented in the Purdue University laboratory to secure additional data. They present a summary of the results. They feel that the exhaust-gas temperatures are high enough so that properly designed manifolds, together with thermostatically controlled carbureter temperatures, should make possible the satisfactory carburetion of fuels considerably heavier than the present "power" gasoline, without seriously limiting the power, efficiency or flexibility of passenger-car engines or causing any engine-maintenance troubles. [Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

P. S. TICE:—It lately has been impressed upon the minds of automotive engineers that at least a close approximation to complete vaporization in the intake is essential. Not only does it increase the utilization of fuel but it is utterly impossible without it to use fuel-metering characteristics in the carbureter that result in maximum utilization. When considering the use of exhaust heat to produce vaporization, it must be noted that as combustion of the fuel in the cylinder become more complete less heat is available in the exhaust. However, the ratio between the heat available and the heat needed for vaporization always increases as utilization is increased.

A study of the curves presented by Messrs. Berry and Kegerreis brings out the fact that all the data presented were obtained under conditions of comparatively small utilization. For instance, consider their curve of exhaust temperature versus mixture-ratio. With the greatest possible utilization, this curve is not only lower on the temperature scale but it has a different shape and a different general slope. What complete vaporization really does is to give to the effective mixture in the cylinders proportions equal to those of the overall or metered mixture. Unvaporized fuel does not burn; hence, the effective mixture is poorer in fuel than the overall or metered mixture by the relative amount of liquid in the cylinders at ignition. There are, of course, other aggravating circumstances. Chief of these is the one that admission of liquid fuel to the cylinders cannot result only in non-homogeneous mixtures.

The brake thermal efficiency of just over 13 per cent at one-half load, as in the curve in Fig. 6 of the paper, presupposes an overall or gross mixture-ratio of between 9 and 10. While it is probable that the brake efficiency here shown was not the maxmium that could have been obtained under the conditions established by the authors at one-half load, it is equally probable that it could not have been much higher. In this connection it is interesting to note that, with complete vaporization and therefore equal distribution and high utilization, such an engine at the same speed and relative load shows a brake thermal efficiency of 22 per cent with a mixture-ratio of between 15 and 16. Experimental observation shows that, in general, with conventional service methods of vaporization, an overall ratio of between 9 and 11 is required to secure an effective ratio of from 13 to 16.

The authors' results on vaporization from a hot plate are interesting, even if they are inconclusive. They at least point out the fact that it is easily possible to secure data from which one can design to secure fuel vaporization.

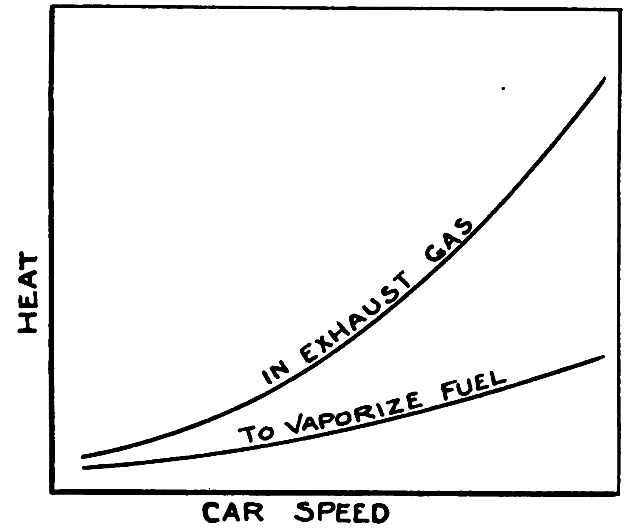


FIG. 4—CURVES SHOWING THE GENERAL RELATION BETWEEN THE HEAT REQUIRED TO VAPORIZE FUEL AND THAT PRESENT IN THE EXHAUST GAS AT DIFFERENT CAR SPEEDS

In any car, it is possible to plot with great definiteness the two extreme sets of conditions surrounding vaporization of fuel by exhaust as shown in Fig. 4. I made such plottings some years ago for several cars that were available for experimental work. I was forced to conclude, with Messrs. Berry and Kegerreis, that the only doubtful combination of conditions might be that existing at the smallest loads at the lowest speeds. But, even

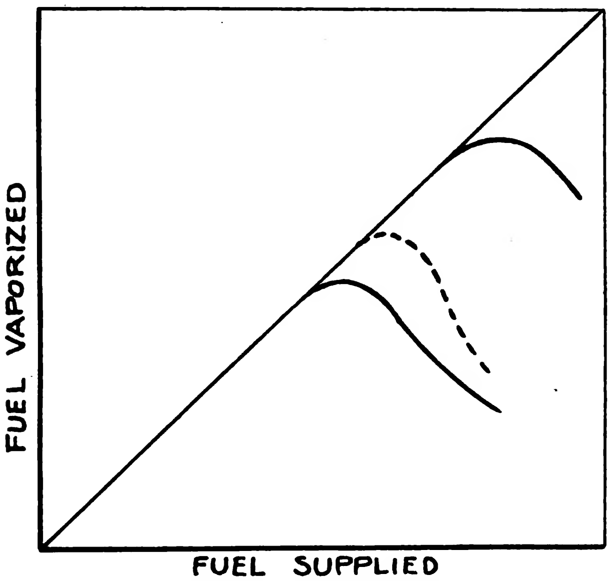


FIG. 5—CURVES OF THE CAPACITY FOR VAPORIZING FUEL

there, considering that the heat is available only at comparatively low temperatures, its quantity and the temperatures at which it is available are sufficient for our needs if advantage is taken of the conditions that exist in a throttled engine. The only thing that the designer is forced to create for himself in such a case is a reasonably efficient heat-transfer from the exhaust gas to the fuel liquid.

My early work directed toward the attainment of this reasonably efficient heat-interchange showed definitely that a simple flow of liquid, either in streams or in a thin film over a heated surface, did not result in a usefully high vaporizing capacity expressed in terms of weight of fuel evaporated from a unit surface in a unit time. The authors' plots of time versus temperature of a hot plate show in some measure why this is so. Furthermore, it soon was found that the effective capacity of a unit surface depends very importantly upon the manner in which the liquid is brought to the surface; this, in general, was independent of the temperature of the surface.

Briefly, the highest vaporizing capacity of a unit surface results from finely spraying the fuel upon a hot surface at such a rate as just to fall short of wetting the surface. When the fuel is so applied, the vaporizing capacity of a unit surface having a given amount of

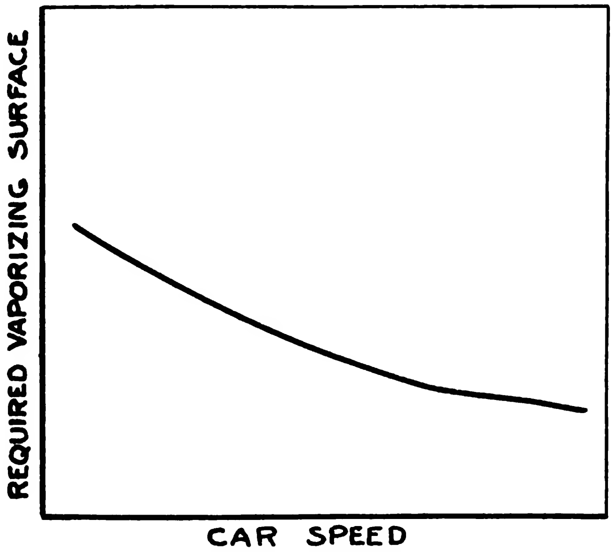


FIG. 6—THE RELATION BETWEEN THE REQUIRED AMOUNT OF SURFACE TO VAPORIZE THE FUEL AND THE CAR SPEED

available heat is an inverse function of the size of the liquid particles or globules. With an intake embodying this idea and arranged so that the vaporized fuel can be quantitatively determined, plottings of capacity assume the general form shown in Fig. 5. Each curve represents a constantly available quantity of heat at a constant temperature. As soon as the surface shows wetting, the ratio Q/V starts to fall with great rapidity. The dotted curve shows the general effect of increasing the division

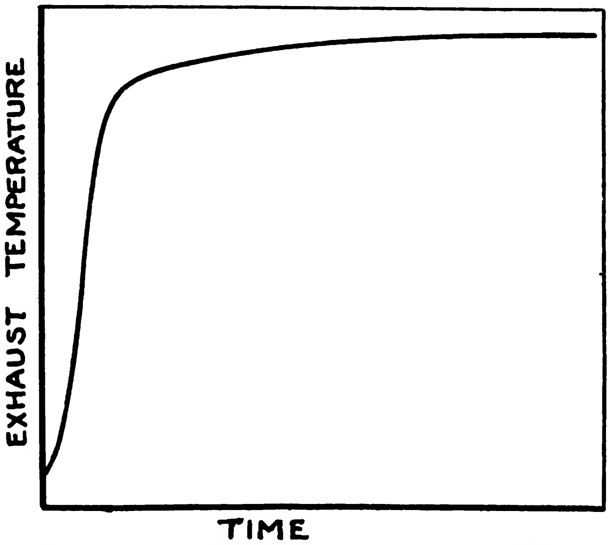


FIG. 7—HOW THE EXHAUST TEMPERATURE INCREASES AS THE TIME OF RUNNING INCREASES

of the liquid before its contact with the heated surface.

Not only does this spraying method greatly increase the capacity of a unit surface under given heat-supply conditions, but it makes possible the uniform loading of whatever surface is employed. Most important of all, I believe, the spheroidal condition is never found at any temperature encountered in such a system. From the spacings of the curves in Fig. 5, it is seen that an increased heat application under car-operating conditions results in an increase in capacity. This increase is substantially one of direct proportionality so long as wetting of the surface is avoided.

A plotting of the required vaporizing surface versus car speed, for any car, assumes the form shown in Fig. 6. Such a result shows that the end of the range of operation that determines the extent of surface for vaporization is that of the small load and low-speed. Having designed for this set of conditions, the remainder of the range takes care of itself. If it were physically possible to apply all the fuel in the form of a fine spray to a surface of 2 sq. in., this surface would be adequate to secure dryness in the intake of a Ford engine, provided heat could be made available to it at a sufficient rate.

The practically controlling factor in the use of the method of finely spraying the fuel upon a heated surface, is not the extent of the surface per se, but the application of the spray to that surface. That is to say, the heated surface must be so located and of such a size as to include all the fuel particles. The fact that the liquid is finely divided presupposes that it is occupying a considerable volume. To return to the case of the Ford engine, the extent of vaporizing surface to give complete dryness under all conditions is represented by the surface and one end of a cylinder 2 in. in diameter and 3/4 in. long, or a total area of 8 sq. in. Further practical service considerations make it desirable to exceed by from two to three times the extent of surface actually needed to secure dryness under normal operation.

Let us consider the case where a man goes to his unheated garage, starts his car, drives off at about 20 m.p.h. and continues to run at that rate until the temperatures throughout the engine shall have come into equilibrium. The first temperature to do so will be that of the exhaust; but one must run for some 20 min. or more before that temperature becomes stable, as indicated in Fig. 7. This means that, for several minutes after starting, liquid fuel will pass into the cylinders and cause more or less trouble in addition to impoverishing the effective mixture.

To practically eliminate this condition, it is my practice to make the extent of the vaporizing surface two to three times that actually needed. This enlargement of the vaporizing surface in no way alters the normal temperatures of the charge, but it does enormously accelerate their rise to normal values.

L. C. MARBURG:—In these curves showing temperatures at varying speeds, how was the variable speed obtained? Was the spark changed or was the speed secured entirely by opening and closing the throttle? If the latter was the case, where was the spark set? It seems to me that the curve must be different with an early spark than with a late one.

E. D. THURSTON, JR.:—How were the exhaust temperatures measured and at just what point? I know of some experiments which showed that, in the movement of the thermocouple or other means employed, a very short distance will make a considerable difference in the temperatures found for the exhaust gases.

R. E. WILSON:—How did the temperature at which this spheroidal condition began compare with the end-point of the fuel? An interesting fact in connection with the work of these authors is that the composition of the mixture boiling at a constant rate on the hot-spot that is described was presumably identical with what we have prepared and termed the "equilibrium solution" in determining the "condensation temperatures" of fuels. It is also interesting to note that the temperature of the liquid when it takes on the spheroidal condition must actually be *lower* than that of the more rapidly vaporizing liquid when the temperature of the metal is lower. In other words, as we go for a considerable distance above the point where the spheroidal condition is approached, the *higher* the temperature of the metal is, the *lower* the temperature of the liquid will be, since the rate of vaporization of the liquid is a good measure of its mean effective temperature. This undoubtedly accounts for the fact that less decomposition was observed when the fuel was in the spheroidal condition than when the rate of vaporization was at a maximum just before the spheroidal condition was approached.

O. C. BERRY:—Mr. Tice has developed a method of vaporizing liquid fuel by spraying it on to a heated surface. As he points out, the amount of fuel that can be vaporized per square inch of surface is greater under these conditions than when the liquid flows onto the heated surface. We are therefore pleased to get his figures showing the rates of vaporization that can be obtained in this way. The fact nevertheless remains that the majority of heated manifolds makes use of the other method, and the figures presented in this paper are directly applicable to these cases.

We do not wish either Mr. Tice's remarks or our own to be interpreted as indicating that the critical condition for a manifold, or the one where failure is most likely to occur, is when operating at low speed and low load. This is more critical than when higher speeds or higher loads are maintained steadily, but the real danger point is when a heavy load is thrown upon the engine immediately following an extended period of slow-speed low-power operation.

In reply to Mr. Marburg, the various speeds were obtained by changing the load on the dynamometer. The throttle was wide-open in all cases for the full-load tests. The spark setting was a compromise and was kept constant at all speeds at the same load during a variable-speed series.

In reply to Mr. Thurston, the location of the thermocouple was near exhaust-valve No. 5. The thermocouple was allowed to project into the intake-manifold, into the gases themselves. Considerable care was taken to insulate the wire from the metal by asbestos, to prevent the flow of heat from the wires to the exhaust-manifold wall. One can well understand that the wires would have considerable heat-conducting capacity and, if they were brought into intimate contact with the colder metals of the exhaust-manifold, the temperature recorded would be much too low. It is true that the temperature will vary markedly with the location of the thermocouple. It is our effort here not to get exact figures that would be universally applicable, but simply to get a general idea of the magnitude of the forces with which we have to deal.

As to Professor Wilson's question of the comparison of the spheroidal state and the end-point, unfortunately I had not thought of it in that way. One can take from the curves the temperature at which the spheroidal state begins, and we have figures showing the distillation curves of the fuel in 10-per cent increments. The end-point is given in each case.

AIR-COOLED ENGINE DEVELOPMENT

BY CHARLES L. LAWRANCE

THE development of air-cooled engines for aircraft never made much progress until the war, when the British attempted to improve the performance of existing engines by a series of experiments leading eventually to the development of aluminum cylinders with steel liners and aluminum cylinder-heads with a steel cylinder screwed into the head. The advantages of these constructions and the disadvantages of other types are discussed. Results are reported of tests at McCook Field on a modern cylinder-design of this type showing good results, that lead to the belief that large air-cooled engines will be produced in the near future, equal in performance to water-cooled engines of the same power. It is claimed that, at present, there is nothing to choose in performance between water-cooled and air-cooled engines of about 25 hp. per cylinder, and that air-cooled engines of this size can be built successfully of the same compression-ratio and having the same fuel-consumption as high-compression water-cooled types.

An explanation is given of the reason for the advantages of aluminum cylinders and head constructions, and a chart is presented showing the temperature on the front and the rear of a large air-cooled cylinder of high output. The question of the cylinder-wall temperature of air-cooled and of water-cooled engines is discussed, and it is indicated that there is not much difference in temperature between the two types. The water-cooled engine is at a disadvantage on account of the number of heat transfers from one medium to another before the heat reaches the air. A statement is given of the reason air-cooled engines can perform satisfactorily with less cooling area than is required for water-cooled engines.

The subject of the resistance of airplanes having air-cooled and of those having water-cooled engines is discussed, attention being drawn to the fact that little is known of the best methods of installing and cowling these engines. Various suggestions are made for possible future development of cowling, to permit airplanes equipped with air-cooled engines to offer as little the resistance as those equipped with water-cooled engines. [Printed in the February, 1922, issue of THE JOURNAL.]

THE DISCUSSION

DONALD MACKENZIE: — I am almost convinced that the air-cooled engine is the future engine for aircraft. Has any measurement been made of the exhaust waste temperature? I believe these tests were made on the Hispano-Suiza engine. It appears that the power carried away in the cooling system was roughly one-half the power developed at the brake. Is it possible to estimate that?

CHARLES L. LAWRANCE:—As I understand the tests made at the Bureau of Standards, the amount of heat absorbed by the cooling system was about 12 to 15 per cent.

MR. MACKENZIE:—That refers to the total heat energy of the fuel, but the loss in brake horsepower would be about twice that amount.

MR. LAWRANCE:—I do not know that any such tests have been made.

S. D. HERON:—Regarding the heat dissipated by the external cooling surfaces of an aluminum-and-steel air-cooled overhead cylinder of the type mentioned in Mr. Lawrance's paper, this has been found to be approximately 60 per cent of the heat equivalent of the brake horsepower. In addition, heat approximating 40 per cent of that developed as brake horsepower is dissipated by the oil, crankcase conduction, radiation and the like.

H. M. CRANE:—Mr. Lawrance has given a very interesting history of air-cooled-engine development. The first thing we notice is that the air-cooled engine is not in its infancy. It is 25 to 30 years old. In fact, the early flying was almost invariably done with air-cooled engines. The trend of thought among airplane enthusiasts was invariably in that direction. It did not seem possible that the water-cooled engine could be used. One of the earliest practical water-cooled engines was the Antoinette, and that was rather an exception. We have Mr. Lawrance's word that the English Channel was first crossed with an Anzani radial engine, which is a fair example of an early type of radial engine. I think the air-cooled engine today can stand on its merits, and that it must admit that it had at least an equal start with the water-cooled engine. I think it started earlier. Even during the war, the water-cooled engine was on the defensive. One reason was that the designer of air-cooled engines visualized a radial engine about 36 in. in diameter, producing about 400 hp. and weighing about 500 lb. Some early advertising of the A.B.C. Dragonfly engine gave figures of that general order, although the engine had a greater diameter than I have stated. The actual results with radial air-cooled engines are different from what we have been promised in size and weight, especially when we reach the larger horsepowers.

What important features of construction do we find in the two engines at present? Most of Mr. Lawrance's drawings show radial air-cooled engines with single cylinders, which make them look reasonably simple. As a matter of fact, there is no comparison between the two types when it comes to rugged simplicity of construction. The 8 and 12-cylinder engines of modern water-cooled design are about as rugged when compared to air-cooled engines as the ordinary automobile engine is when compared to the water-cooled aviation engine. Mr. Lawrance has compared a very modern uptodate radial air-cooled engine, which I know is the result of years of painstaking effort on his part, with a water-cooled engine, which was produced in large quantities under the stress of war, and passed daily tests on the basis of the figures given today.

The only thing to do is to compare the latest uptodate air-cooled engine with the latest uptodate water-cooled engine under the same operating conditions, where the mean effective pressure of the water-cooled engine reaches 145 lb. per sq. in. This engine weighs 620 lb. and develops 400 hp. at 2000 r.p.m. on an extremely low gasoline consumption of less than 0.45 lb. per b.hp-hr. If we add the weight of radiator and proper amount of water, we still have a lighter weight than that of any air-cooled engine, which shows signs of running satisfactorily and develops like horsepower. When I say the water-cooled engine is a more rugged engine, I am willing to include with the water-cooled engine the necessary radiator and the attachments that go with it. I think no such radiator as was described for 220-hp. engines is necessary, because I am strongly of the impression that the 300-hp. engine was cooled with two radiators, each of which weighed less than 30 lb.

Granting that the radial air-cooled engine is justified

as an engine, there is nothing to indicate that it is a good airplane engine.

I went to France in 1915 with the responsibility of choosing an engine that could be built in the United States. The Salmson plant interested me most and was by far the best operated in Paris at the time. It had already produced a 250-hp. engine which was running excellently, but the plant was absolutely idle. There was not an order in hand except for a small number of engines for Russia. This was because the airplane designers recognized the fact at that time that the form of the engine was about the worst possible for mounting in an airplane, due to its high head-resistance. Later on, it is true, the stability of this engine, coupled with the services of a progressive and uptodate airplane designer, resulted in producing a very efficient machine in this plant, but the machines used in the war were of a distinctly slow-speed type, compared with those we have in mind today. We heard much during the war about speeds of 130 and 140 m.p.h., but they were not realized. The machines of 110 m.p.h. were the speediest of that time.

Not only is the form of the engine bad from the aerodynamic viewpoint, but it is bad for the mounting of accessories; these are bound to be important points in commercial work, due to the necessity of wireless and other forms of electrical generating apparatus being driven by the engine. The engine itself is not particularly accessible. It is difficult to mount it on an airplane and it does not compare at all favorably in this respect with the water-cooled engine. The air-cooled engine is not well adapted to being overhauled and reassembled. It is of the porcupine type. There is nothing to set it down on. It has things sticking out in every direction and must be suspended in order to take it apart successfully. Breakage of the very light fins, which are essential to the operation and light weight of these engines, is a common occurrence if they are not handled with extreme care, and part of the cooling effect is lost when the fins are broken.

When the cooling, mean effective pressure and various tests of the kind that have been made on single-cylinder engines are done with a full knowledge of what multi-cylinder construction means, the form of test is very edifying, but may lead to great misconceptions. The single cylinder is ideal from every viewpoint regarding mixture-strength and similar considerations, and everything indicates that the correct mixture-strength has more to do with the low temperature of the exhaust-valve and the cylinder-walls than anything else.

It is easy to reach these conditions in a single-cylinder engine; in a multi-cylinder engine it is not. Unless they are inside the safe limit of cooling, engines that run successfully with a single cylinder are apt to show serious heating difficulties in one or more of the cylinders when put in a multi-cylinder form with its inseparable differences of distribution.

The problem of parasite resistance is still undetermined. One thing which must be decided before going into that matter is what we are to do with the exhaust. I should have mentioned this in regard to the radial air-cooled engine; it is a bad engine from which to handle the exhaust. Part comes from an ideal place below the machine and part directly into the face of the pilot, unless the engine has a manifold. If it has a manifold, the parasite resistance is greatly increased. If the engine is cooled properly and has a fairly large diameter, the pilot's view in the most important directions, forward and downward, is about as bad as it could be. It is difficult to comprehend how a pilot can be mounted behind a 50-in. disc and see much in the direction he is traveling. This is an important feature, especially in military machines, and it seems worth considering in commercial machines. As no one has operated large, air-cooled engines successfully in any other form, I think we must consider the radial form as possibly the only successful form at present where power results approaching those of water-cooled engines can be expected. For that reason, we have a right to criticise this form in that respect.

We do many things in different ways. Sometimes we try to make one part do two things and at another time we find it is better to have two parts, each particularly suited to its own work. In the indirect cooling of the water-cooled engine, the radiator is designed only for maximum cooling and minimum head-resistance, which can be accomplished. If the radial engine is restricted from the manufacturing point of view, the fins cannot be put on in the proper direction. This is probably not at a right angle to the central line of the cylinder; it might be better if they were put on at an angular slope in respect to this line.

In the matter of cooling, the airplane designer should be willing to sacrifice head-resistance. That is true with the cooling of the rear of the cylinder, which produces the serious parasite resistance. I have seen photographs of many of the mountings of these powerplants and do not believe for a moment that the cooling of the rear of the cylinders as shown in those photographs is properly taken care of at all. There is an attempt to streamline the cylinders from the back, to prevent the turbulence of the air behind the cylinders that is necessary for proper cooling.

MR. HERON:—Evidently Mr. Crane does not grant the air-cooled engine a single advantage over its rival, and finds only ground for not altogether well informed or unbiased criticism. Although it is granted that the Hispano-Suiza engine was undoubtedly the most generally useful to the Allies, yet in the British army the air-cooled, stationary, V-type engine rendered much good service to the cause and required much less maintenance. Most of the necessary maintenance could be done without removing the engine from the airplane. The single-cylinder-engine test certainly does not represent air conditions, but something much more severe. Cooling air-blast velocities are almost always lower than those obtained in the air, and all the British figures and the later figures of the engineering division of the United States War Department represent results maintained on continuous full-throttle at ground level.

C. B. DICKSEE:—Mr. Lawrance's paper forms a valuable addition to the information available on the subject of air-cooled engines. The air-cooled engine offers many advantages to the automotive as well as to the aeronautical engineer; it provides one solution of the fuel problem, as it will handle the heavy ends without difficulty and, when it is heated-up, if provided with a short and direct manifold, will run on kerosene without a vaporizer.

When mentioning cylinder temperatures, the mixture-strength must be taken into consideration, as this has a very great bearing on the actual temperature recorded. As an illustration of this, some figures taken from a cylinder of 3⅜-in. bore and 5-in. stroke, running at 1400 r.p.m. with an axial air velocity of only 1750 ft. per min., are of interest. They are given in Table 1. Various curves also are shown in Fig. 8.

The airflow being axial, the temperatures around the working barrel were very uniform, there being only a 70 to 80-deg. fahr. maximum difference at the upper end and less than 30 deg. fahr. difference at the lower end.

Greater differences, of course, existed on the combustion-chamber. The cylinder was of cast iron fitted with 60 sheet-steel fins, 0.05 in. thick and 0.75 in. high, cast in, so as to produce a perfect weld. This provides a very satisfactory cylinder for moderate outputs. The engine not being intended for high duty, no attempts have been made to obtain high outputs. The air velocity used would, probably, be too low for continuous operation at the output recorded. There was, however, no sign of detonation. The mixture-strengths were obtained by converting exhaust analyses taken with an Orsat apparatus into pounds of air per pound of fuel by Dr. Watson's combustion chart. The last column of Table 1 will answer Mr. McKenzie's question as to heat carried away by the cooling air. The actual figure will vary with the power output and air-velocity as well as mixture-strength, just as it does in water-cooled engines; but the values are of the same order.

It is possible that the lack of satisfaction Mr. Lawrance obtained with a bolted-on head was due not to the fact that the aluminum was not carried well down the side of the combustion-chamber, but to the distortion produced in bolting-down. Distortion of the valve seats is very easily produced in this way and any leakage will produce excessive temperatures. An increase in temperature of 250 deg. fahr., due to a very slight leak in the spark-plug gasket has been noticed. If Mr. Lawrance will replace the few large bolts with a greater number of small ones, his difficulties probably will disappear. The British Air Board reports having produced a satisfactory cylinder of this type, the size being, I think, 6½ x 8 in.

There is no mystery as to the quantity of heat that can be taken care of by any given fin. If the thermal conductivity of the material, the dissipation constant for the surface, the velocity of the air and its temperature difference from that of the surface are known, the quantity of heat dissipated by any given fin can be readily calculated.

Mr. Heron:—It has been found that for aluminum-and-steel cylinders of the type shown in Mr. Lawrance's paper, the maximum cylinder-temperature is developed at the best compression-ratio on an air-fuel ratio of 12 or 13 to 1 by weight. Mr. Dicksee mentions calculating fin sizes and sections. Much useful work can be and has been done along these lines; however, the theoretically correct fin, particularly when made of high-conductivity material, is of such section that it cannot be produced commercially and, even if it could be, it would be excessively fragile. He attributes most of the unsatisfactory performance of the bolted-on detachable-head cylinder to distortion. The R.A.E. 21T 5½ x 6½-in. bolted-on head cylinder is cited as an example of a successful bolted-on head, but this is not intended to be detachable in the generally accepted sense. No evidence that I know of has shown that the power output or fuel-consumption of this cylinder has proved as good as that of similar types with cast-on or screwed-on heads.

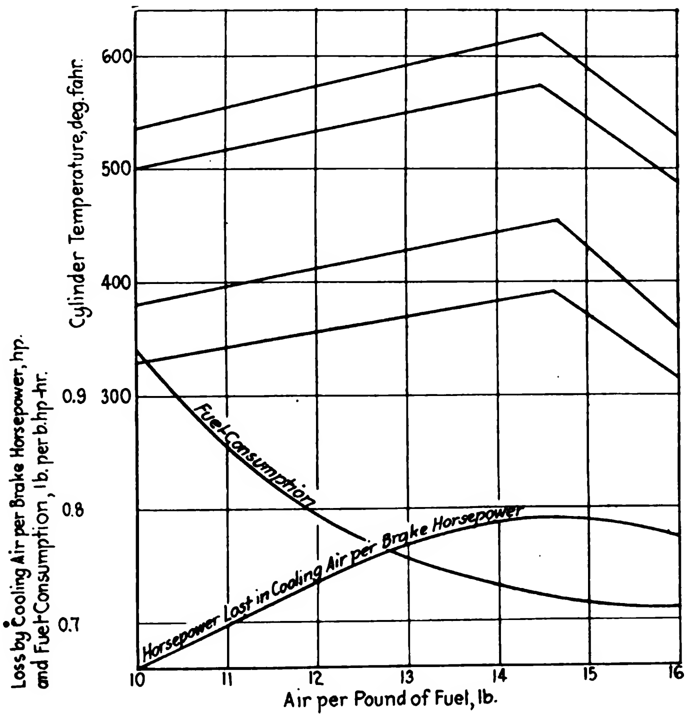


Fig. 8—Relation between Cylinder Temperature and Mixture-Strength in a 3⅝ x 5-In. Aircraft Engine Running at 1400 R.P.M.

Tests by the engineering division of the War Department on two cylinders of composite aluminum-and-steel construction, and of identical design, except that one has a cast-on head and the other a bolted-on detachable head, have shown the bolted-on head to be inferior as regards output, fuel-consumption and temperature developed. The bolted-on head is liable to leak gas at the joint and, if the flame gets between an aluminum head and a steel or cast-iron barrel, the former is usually burned out rapidly. Axial heat-flow from the head to the barrel is practically non-existent with a bolted-on head, and experience indicates that such heat-flow is important.

A design in which all heat given to the head must be dissipated by that part seems inferior to a type where heat flow is possible and the barrel is allowed to dissipate part of the heat given to the head. A screwed-on head of the type used by the engineering division has much more cooling-fin surface integral with the head than will exist with a detachable head in which the head ceases and the barrel starts at the top of the piston travel; and considerable heat-flow from the head to the barrel is possible in view of the fact that the surface of the head in

TABLE 1—RESULTS FROM 3⅝ X 5-IN. CYLINDER AT 1400 R.P.M.

Mixture-Strength, Air per Pound of Fuel, lb.	Brake Horsepower	Average Temperatures, deg. fahr. Top of Head[a] (A)	Side of Combustion Space[a] (B)	Working Barrel[a] Top (C)	Working Barrel[a] Bottom (D)	Fuel-Consumption, lb. per b.hp-hr.	Loss by Cooling Air per B. Hp., hp.
10	5.10	535	500	380	330	0.940	0.660
11	5.10	554	513	392	342	.....	.....
12	5.10	575	530	410	356	0.795	0.735
13	5.10	592	548	424	367	.....	.....
14	5.00	612	570	442	382	0.736	0.790
15	4.65	594	548	410	358	.....	.....
16	4.25	530	491	360	316	0.710	0.775

[a]Letters correspond with those on the temperature curves in Fig. 8.

contact with the barrel is approximately 130 per cent of the piston area.

D. R. HARPER:—The results of some of the measurements made at the Bureau of Standards may throw some light on questions that Mr. Lawrance has mentioned more or less in speculation. Almost no data regarding the head-resistance of air-cooled cylinders are as yet in the literature of the subject. The suggestion that the head-resistance is rather higher than is often supposed must not be interpreted as condemning the air-cooled engine, for the latter has its field and, regardless of the loss of power due to head-resistance, it may be very much needed in that field.

Whenever, in designing, we combine two distinct functions in a single part, we are likely to sacrifice some of the effectiveness of both functions. The cooling capacity of the air-cooled cylinder is naturally less than that of the water-cooled one, where the power functions and the cooling functions have been separated. The water radiator has been brought to a wonderful degree of development, while air-cooled cylinders, in spite of their ability to utilize a much greater temperature-head, are seriously handicapped on account of offering more head-resistance for the same cooling power than do the well designed water systems.

The measurements, which form the basis of these statements, were wind-tunnel experiments in a series, made by the Bureau of Standards for the engineering division of the Air Service. The air-cooled cylinders or radiators were mounted in a free-air or "unobstructed" position. When we consider the air-cooled engine as mounted in a fuselage, there are mutual interference effects of the several cylinders and modification of the air-flow by the fuselage, so that the figures given would be changed; whence, caution must be exercised in drawing general conclusions. The figures are of interest in suggesting the order of magnitude involved. In the free-air position, a single-cylinder assembly of each of the air-cooled engines offered a head-resistance about 30 per cent greater than that of an equivalent water radiator. The cylinders used were typical of the late-war and post-war eras and, although including a Lawrance aluminum cylinder, were mostly types now considered obsolete and not worthy of the expenditure of the time required for careful investigations. The measurements were distinctly of preliminary character and no great significance attaches to the figure of 30 per cent. An analysis of the contributions to head-resistance by various parts of an engine was then made to see whether appreciable savings in windage might be effected by changes in design.

The measurements were along the lines indicated by Mr. Lawrance in mentioning the crusader cowl, and afford quantitative data for consideration in designs of this nature. The results obtained proceed from observations made with sufficient care to warrant publication and, as I believe a report will soon be printed, I will condense the account of the work to a minimum. Working with a large wind-tunnel at the Bureau of Standards, Miss L. Butler and C. F. Zobel measured the head-resistance of a Lawrance cylinder-assembly in successive stages of stripping-off valve push-rods, rocker-arms, springs, ignition cables, intake tubes and the like. The results indicate the contribution to head-resistance of each part, mounted in its relative position, with the cylinder as a whole in a free airstream. The total contribution by parts thus removable was 16 per cent of the total head-resistance of the complete cylinder. If, therefore, parts that need not be in the airstream because they contribute little or nothing to the cooling could be enclosed in a perfect cowl or zero resistance, the total saving in windage would be about 16 per cent.

G. J. MEAD:—In commenting on Mr. Lawrance's paper, I suggest that we look for a moment at the way in which radial and water-cooled engines of equal power compare when measured by what might be called the five prime requisites of an aviation engine, as considered in the following paragraphs.

It must be granted that the reliability of a radial engine is at least equal to that of a water-cooled type, especially as the same accessories and fuel system are used with both. As we all know, it is usually the accessory systems that cause failure in the air, and not the engines themselves.

Performance includes two items. The first is the effective power required for take-off and for satisfactory operation at working altitudes, with the specified fuel. The effective power, or power available for moving the airplane over and above that required to propel the powerplant, is probably less in the case of a radial engine than in that of a water-cooled engine with radiator, especially in large engines. This is a question that must be settled by actual flight tests. It is hoped that before long the same airplane will be flown with both types of powerplant, each having the same power at sea-level. The cause of possible reduction in effective power is the larger head resistance of a radial engine. Radial engines excel slightly, perhaps, in the second item of performance; that is, low powerplant weight per horsepower per hour. The elimination of water, radiator and piping gives them an advantage, even though comparatively low mean effective pressures are developed.

The durability of radial engines in service has yet to be proved. If care is used in proportioning the bearings and adequate lubrication is provided, it is doubtful whether failures of these parts will occur. On the other hand, I question seriously the ability of the valve-gear to stand up, owing to the large clearances between the cams and the valves that develop in operation on account of the expansion of the cylinders. It should be borne in mind also that aluminum cylinders with thin aluminum fins are not durable. If the fins are really necessary for satisfactory cooling, the efficiency of such cylinders in service is bound to drop.

Our experience with air-cooled engines has led us to believe that failures are due to the breakage of valves and springs. It seems to me that the work done in England on the Cosmos engine, now known as the Bristol, is a good indication that this is so. It shows an effort on the part of the designer to make use of a type of valve gear intended to eliminate this difficulty. It seems that the push-rod-operated valve will be used for some time to come.

Air-cooled cylinders of cast-aluminum construction are easily damaged. Mr. Crane mentioned the porcupine type. If the cooling of such cylinders is due to the fins, the efficiency will be less if many fins are broken off.

Most of the requirements of an airplane powerplant, such as being readily mounted, easily started and accessible, are met equally well by the radial and the water-cooled types. Proper vision, especially in military types of aircraft, is difficult with radial engines, and is apt to become a serious matter with large engines. Due to the compactness of the powerplants, the maneuverability of craft equipped with radial engines probably would be better than those having water-cooled engines. Radial engines are but little more compact than water-cooled, eight-cylinder, V-types. The performance of an engine in flight, throughout its speed-range and at different alti-

tudes, is an important factor in plane requirements, and involves the necessity of temperature control for the engine cylinders. No satisfactory method of shuttering radial-engine cylinders, as is done with radiators, has been evolved, so far as I know. Owing to the great conductivity of aluminum, which makes the present-day radial-engine possible, it is believed that the engine will cool-down very rapidly in a glide. For military work, this drawback must be overcome before the engine will be entirely practicable. Smoothness of working and flexibility are apt to be seriously affected by lack of proper temperature control.

The first costs of a radial engine and of a water-cooled engine, when they are produced in equal quantities, would undoubtedly be about the same. The cost of upkeep will depend to a great extent on the durability of the engine. This question, as already pointed out, has yet to be settled by service tests.

Summing up the above analysis, we find that radial engines have yet to be tested in service to prove how they compare with the best water-cooled engines with respect to three items: effective power, durability and controllability of the engine under service temperatures. The Wright Aeronautical Corporation is developing for the military authorities a large radial engine with 5⅝ x 6½-in. cylinders, and a displacement of 1453 cu. in. Two of these engines have been built and the first one has been running for some time. The maximum power developed was 350 hp. at 1800 r.p.m., with a mean effective pressure of 106 lb. per sq. in. This, so far as I know, is the largest radial engine which has been successfully operated in the United States. New cylinders are being developed which give a promise of 120 lb. per sq. in. mean effective pressure. These will permit the engine to develop 350 hp. at 1600 r.p.m., or 400 hp. at 1800 r.p.m. The final engine of this type will weigh between 750 and 800 lb., which will be about 2 lb. per hp. It is interesting to note that the best figures for a water-cooled engine, including radiator and water, are 2.2 lb. per hp.

I believe that radial engines will fulfill certain requirements satisfactorily, particularly those of some kinds of military service. Their advantages for all purposes have not been demonstrated and until service tests of sufficient duration to settle the doubtful points shall have been conducted, no one is justified in considering them beyond the experimental stage.

R. W. A. BREWER:—This controversy between air-cooled and water-cooled engines appears to hinge on the suitability of the mounting of the air-cooled engine. I believe the air-cooled engine can be made as efficient as the water-cooled engine. F. W. Lanchester's papers before the Institution of Automobile Engineers contain much matter on air-cooled engines that is extremely valuable.

I used a machine with an Anzani engine for experimental work in 1909, just after Bleriot flew across the English Channel, and also one of the first Gnome engines. In those days, although the air-cooled engine was young, the Wright engine was partly air-cooled; its cylinder-head was air-cooled. We got an overall efficiency with the Gnome and its propeller that was comparable with that of any other type of engine, for the reason that propeller flutter was eliminated. The periodic vibrations of the crankshaft, a serious factor in the efficiency of propellers, did not enter. By eliminating propeller flutter we increased the efficiency of the propeller and made up for any small loss due to engines of this type. Somebody has referred to the cylinder distortion caused by the difference in temperatures at the front and the back of the cylinder. The piston-ring of the Gnome engine was one of its interesting details. It was an L-shaped, gun-metal ring held out to the cylinder barrel by a steel ring. There might be distortion and yet the ring would conform to the bore of the cylinder.

CAPT. GEO. E. A. HALLETT:—Airplane designers in the engineering division apparently consider the head-resistance of radial engines to be higher than that of the best water-cooled engines. While the plan is not to use radial engines in planes of extremely high speed, from a military viewpoint the air-cooled engine, of radial or any other type, is advantageous. A large percentage of forced landings is due to troubles in the cooling system, such as cracked water-jackets, radiator leaks, loss of water through evaporation or boiling and in some cases

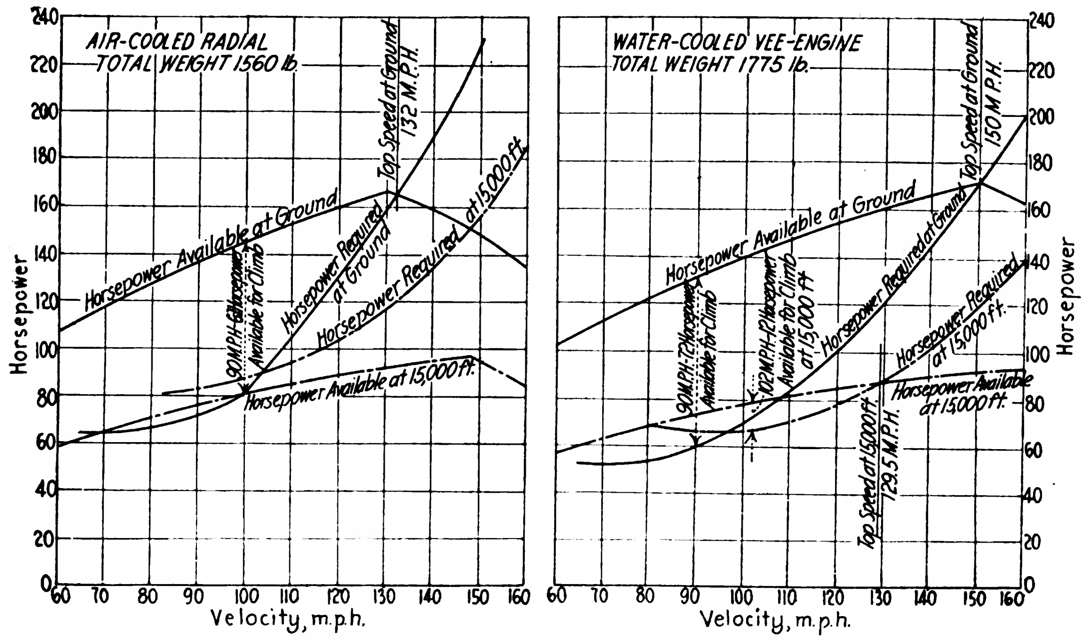


FIG. 9—COMPARISON OF THE LIBERTY ENGINE WITH AN AIR-COOLED RADIAL TYPE AS REGARDS POWER AND SPEED AT VARIOUS COOLING-AIR VELOCITIES

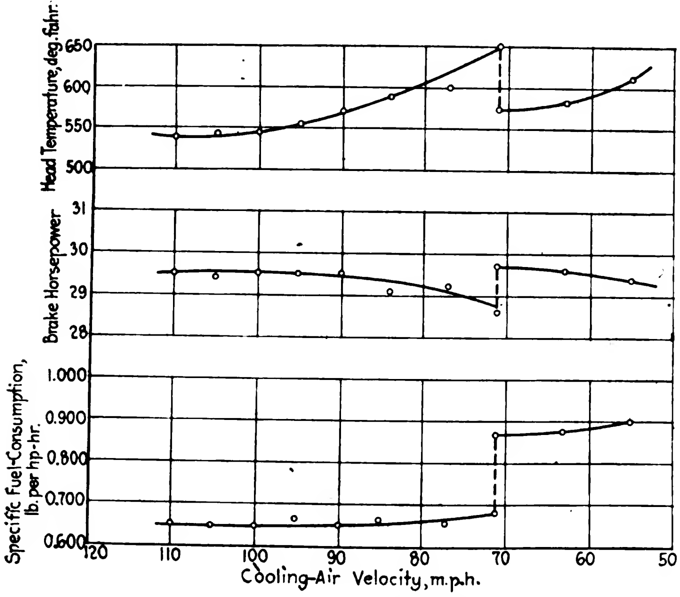


FIG. 10—RESULTS OF A TEST OF A $5\frac{1}{2}$ X $6\frac{1}{2}$-IN. AIR-COOLED CYLINDER MADE BY THE ENGINEERING DIVISION OF THE AIR SERVICE

even freezing. We feel that we are thoroughly justified in developing air-cooled engines for military purposes for this reason, and also because they are less vulnerable to machine-gun fire.

Some interesting reports of brake mean effective pressures and fuel-consumption in English engines have caused us to be skeptical because we have never seen them checked up. Recently Mr. Heron, who worked for years with Dr. Gibson at Farnborough in England, has designed a cylinder which we have constructed and which has given excellent results. Both Mr. Lawrance and Mr. Mead have referred to this cylinder. Not only has it shown a brake mean effective pressure of more than 130 lb. per sq. in., and a capacity for going higher, but it has done this on a fuel-consumption as low, in some cases, as 0.52 lb. per b. hp-hr. This compares favorably with water-cooled cylinders running at a similar compression-ratio, and we believe it is able to do better.

The most interesting thing about this two-valve cylinder has been the cooling of the exhaust-valve. It is a $5\frac{5}{8}$ x $6\frac{1}{2}$-in. cylinder with a compression-ratio of 5.4 or 5.5 to 1. The Liberty single-cylinder engine with which I make a comparison in Fig. 9 is 5 x 7 in. and uses the same compression-ratio, but develops only 120 lb. per sq. in. brake mean effective pressure. The exhaust-valve in the air-cooled cylinder runs cooler; that is, it shows a wider black band around the seat than does the Liberty valve, in spite of the former running at about 10 lb. per sq. in. higher brake mean effective pressure. In short, the air-cooled cylinder shows better exhaust-valve-seat cooling than the Liberty water-cooled cylinder does.

It seems to me that we are failing to keep water in contact with the cylinder-head in water-cooled engines. We have a bubble sheet that holds the water away from the cylinder-head pretty effectively while developing high powers. In air-cooled cylinders we have no bubble sheet. We may get better cooling of the exhaust-valve in well developed air-cooled cylinders than we have so far been able to obtain with thin steel, water-cooled cylinders.

We found during the war that it took about one-half the number of man-hours to overhaul a rotary engine that was required to overhaul a V-type, water-cooled engine, because we used ball bearings and no long crankcase with its troubles in aligning the crankshaft bearings and had no water connections. While it is true that the radial engine may need to be handled more carefully than the water-cooled engine, it has the advantages of ball bearings and a short crankshaft. We cannot make a very good job of overhauling a rotary engine without special tools developed for such work, but those can be developed also for the radial engines.

C. F. TAYLOR:—Mr. Lawrance has presented an excellent paper covering the development of air-cooled aviation engines. One point concerning which a fuller discussion would be of interest is the marked effect of the quality of the mixture on the performance of air-cooled cylinders. The data given on specific fuel-consumption for the various cylinders and engines do not represent the lowest consumption possible, but rather the lowest consumption at which it is considered practicable to operate the engine in question. It should be remembered that the chief controlling factor in fuel-consumption is the quality of the mixture fed to the cylinders, and that even cylinders of poor design can be made to show a surprisingly low specific fuel-consumption if supplied with comparatively lean mixtures.

In air-cooled engines of exceptionally good design, the practical low limit of fuel-consumpton, as in the case of good water-cooled cylinders, is the point at which the power output begins to decrease on account of insufficient fuel to utilize all the air in the cylinder. In most air-cooled cylinders, however, the power decreases on account of excessive value and head temperatures before the point of insufficient fuel supply is reached. This is because the average air-cooled cylinder depends to some extent on cooling by the excess fuel in a rich mixture, to keep the combustion-chamber and exhaust-valve temperatures within practical limits.

The important part that excess-fuel cooling may play in a cylinder of mediocre design is illustrated in Fig. 10, which shows the results of a test by the engineering division of the Air Service, on a $5\frac{1}{2}$ x $6\frac{1}{2}$-in. air-cooled cylinder of aluminum and steel construction. The cylinder was tested at full power with a mixture-ratio giving a specific fuel-consumption of 0.65 lb. per b.hp-hr. and the air-blast speed was reduced gradually from a maximum of 110 m.p.h. It will be noted that the cylinder-head temperature, taken at the hottest point, rose steadily as the air speed was reduced. At an air speed of 71 m.p.h., the head temperature was considered dangerously high and the mixture ratio was adjusted to give a specific fuel-consumption of 0.87 lb. per b.hp-hr. As will be noted in Fig. 10, this restored the power output and head temperature to the values that formerly existed with a 90-m.p.h. blast. In other words, a small increase in the gasoline-air ratio was as effective in cooling the cylinder as an increase of 20 m.p.h. in the blast speed.

A. L. CLAYDEN:—There appears to be an assumption that, although the direct air-cooled engine may be in its infancy, the water-cooled engine is in its old age; but the latter is not true. First, we do not know everything there is to know about water-cooled engines and, second, we do not utilize all we know. The weights of the water, the radiator and the water connections are considerably in excess of what they might be if we went to the limit of everything we know. It is a very surprising fact that a majority of the new machines being designed today for commercial purposes are provided with inefficient water-cooling equipment. I know of many instances where the designers of airplanes did not appear to appreciate that there was anything worth studying in regard to the water-cooling arrangement. One subject about which very little is known is the rate of transfer of heat from a cylinder to the water. It is believed that by narrow-

ing the jacket and increasing the rate of flow through it, designers could reduce very substantially the weight of water and to some extent the weight of cylinder, obtaining at the same time a mean temperature in the cylinder with a narrower range between the extremes than those at present. In other words, the temperature of the cylinder in water-cooled engines will vary between 400 and 240 deg. fahr., or something on that order. Under the best possible conditions and with properly designed water-passages, that range undoubtedly can be reduced so as to bring the maximum to about the boiling point; although I do not know whether that will have any particular importance.

I noticed a test recently that was rather interesting. The normal temperature at the exhaust in an automobile engine was about 240 deg. fahr. As soon as steam was observed in the outlet water, the temperature of the exhaust-valve rose to over 400 deg. fahr., an almost instantaneous rise that merely indicated where the steam was. If the air-cooled engine really begins to push the water-cooled engine hard, the water-cooled engine advocates have plenty of resources.

H. S. McDEWELL:—As I work with both water-cooled and air-cooled engines, I hold no brief for either type. I wish, therefore, to bring out some points that Mr. Lawrance has not mentioned, and to amplify some of his statements.

In speaking of heat transfer, from hot gases in the cylinder to the cooling system, Mr. Lawrance has omitted some of the steps. These are indicated in Fig. 11; for a cylinder constructed with a single thickness of metal at the left, and for a cylinder built-up of two metals, at the right. The lines bounding *b*, at the left, represent the cylinder wall. The horizontal and sloping lines denote the temperatures existing in the various parts of the system, measured from an assumed datum, or zero-temperature line. It is known that in a transfer of heat from a gas to a fluid of any type through a metal there is a great temperature-drop in the fluid films that lie close to the metal surfaces. These films are represented by the lines bounding *a* and *c*. The drop through the hot, dead-gas film *c* will be somewhat of the order indicated by $t_1 - t_2$. The temperature-drop in heat transfer through the metal *b*, will be of a very much lower order, as indicated by $t_2 - t_3$. Again, in transferring heat from the metal to a fluid, there will be another dead film *c* and again there will be a very serious temperature-drop as indicated by $t_3 - t_4$, to determine the mean temperature of the cooling medium t_4. In an air-cooled engine, the three necessary steps are represented at *a*, *b*, and *c*; *a* being through the first gas film, *b* through the metal of the cylinder and *c* through the second dead-gas film to the cooling medium. In a water-cooled engine we have another metal surface in the radiator and another drop through the dead film, a very small drop through the metal and a further drop through the second film to the temperature of the cooling medium. Therefore, there are twice as many transfer-steps in the process of water-cooling as obtain in air-cooling.

I object to one statement by Mr. Lawrance, that the water-cooled engine is handicapped by the number of heat transfers, all of which tend to increase the ultimate temperature on the inside of the cylinder. Previous to this Mr. Lawrance demonstrates that the temperatures on the outside of the cylinder wall of both air-cooled and water-cooled engines are approximately the same. Taking the case of the Hispano-Suiza engine, we have a

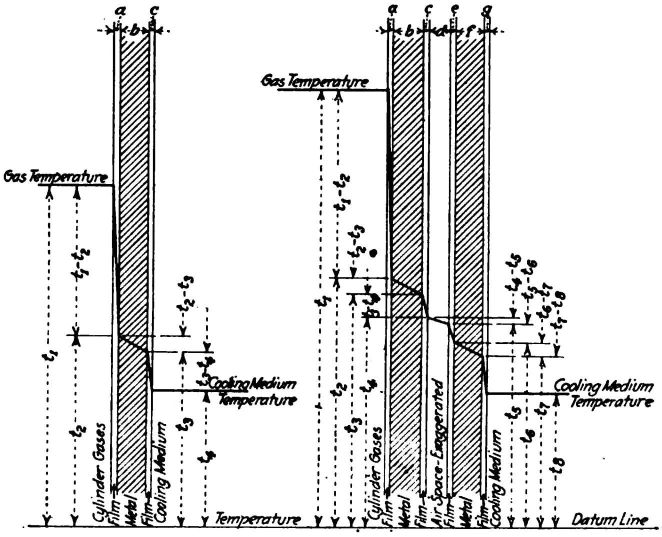


FIG. 11—DIAGRAM ILLUSTRATING THE TRANSFER OF HEAT FROM AN AIRCRAFT-ENGINE CYLINDER TO THE COOLING MEDIUM

transfer through two metals, with an infinitesimal gap between, no matter how perfect the manufacture may be; there is thus an unavoidable lack of thermal bridge when such a construction is involved. Consequently, as shown at the right in Fig. 11, we have an additional drop in temperature through *d*, a still further serious drop through *e*, another small drop through the second layer of metal at *f* and a final drop through the film *g*. If the cooling-temperatures t_4 and t_8 are the same in both the types of construction indicated in Fig. 11, it would be reasonable to presume, from heat-transfer considerations, that the temperature inside the cylinder would be less in the case of a single thickness of metal. Granted that the air-cooled cylinder has been designed in which the temperatures inside and on the outer wall are comparable with those obtaining in water-cooled cylinders, the mean temperatures of the cooling medium due to these heat-transfer considerations must be approximately the same irrespective of the medium. The fact that water boils at 212 deg. fahr. at sea level is not really a handicap in operation, because we must decide upon the safe limit of temperatures of engine parts and stay within it, presuming a properly designed water-cooling radiator system.

Regarding the matter of handling engines while being overhauled one thing must be kept in mind; that is, that, while the factory crew may be well trained, both Army and Navy engines may be sent to some far-distant station which is not equipped with special apparatus. To have doughboys handle a porcupine engine during its overhauling is a serious proposition.

In considering the comparative resistance of the air-cooled and the water-cooled engine, I refer to Grover C. Loening's paper on Engine Shape as Affecting Airplane Operation.[7] He made a good comparison between water-cooled and air-cooled engines and pointed out that the question of relative weight is of minor consideration and that head-resistance is the primary factor. Most persons speaking in favor of the air-cooled as against the water-cooled engine refer to the radiator as a nose radiator. The nose radiator is obsolete. It stands to reason that if a radiator is mounted in front of an engine, the area of that radiator must be increased enough to compensate for the obstruction that is at the back of it in the form of the engine. The latest and best practice in radiator installation in planes is to put the radiators in the clear, not only in the mounting but in the actual construction.

[7] See S.A.E. TRANSACTIONS, vol. 16, part 1, p. 577.

There have been great improvements lately and, as a result, radiators having a very materially increased figure of merit have been produced and actually installed in some powerplants.

I have refigured a portion of Table 2 in Mr. Loening's paper, comparing the Curtis CD 12, the Hispano-Suiza or Wright Model H and the Cosmos-Jupiter engines, assuming as a basis of comparison a propeller weight in pounds of 2.5 times the square root of the horsepower. I have also assumed first, a weight of radiator and water of 0.65 lb. per hp., in agreement with older practice; and, second, a weight of radiator and water of 0.56 lb. per hp., which agrees with later practice using the improved radiators mentioned above. In both cases the resistance of the Cosmos-Jupiter engine was reduced below that given in the original table, in accordance with the data given by Mr. Lawrance on the effect of the crusader cowl. On the first basis the total resistance per horsepower of the engine and of the retractive radiator and the drift of the wing necessary to lift that powerplant, figure out to be practically identical for the three engines at 200 m.p.h. When the data for the better types of later radiator are included, the figures favor the water-cooled engine.

One of Mr. Lawrance's engines had completed all but 4 hr. of the 50-hr. test when I left Washington, and the latest data from it happen to be slightly better than the figures quoted by Mr. Lawrance. Running at 1775 r.p.m., the actual power developed was 228.7 hp. Corrected for barometer and temperature, it developed 217.7 hp., which gives an actual mean effective pressure of 129.5 lb. per sq. in., or a corrected mean effective pressure of 123.3 lb. per sq. in., which is high. The fuel-consumption was 0.58 lb. per b.hp-hr. and the oil-consumption was exceedingly low, being 0.013 lb. per b.hp-hr. The reason for the high fuel-consumption is that, due to the Navy program, this test was run with the utmost expedition to develop what the engine would actually do in the matter of reliability; it was not tested for economic performance, but to develop the weak structural points. Consequently, very little attention has been paid to carburetion. I have no doubt that the fuel economy could be improved. Another factor is that the carbureters on this engine were designed specifically for a very low fuel-consumption at cruising speeds, rather than a necessarily low consumption at full-throttle. At 0.9 of the rated horsepower, we have shown a fuel-consumption of about 0.51 per lb. per b.hp-hr.

I wish to bring to the attention of those who are working on air-cooled engines the same liability to trouble that is met in the case of water-cooled engines; that is, the possibility of trouble at either altitude or ground-level under cold, damp conditions, due to the formation of ice in the manifold. The water-cooled engine has the defect that the water-jacketing on the manifold is not entirely satisfactory. A greater amount of heat than is available in the water is necessary to prevent the formation of ice absolutely.

H. E. MORTON: — The comparison of air cooled with water-cooled engine is always an interesting subject. The development of the air-cooled engine during the last few years has been very remarkable. Mr. Lawrance refers to the several heat-transfers in a water-cooled engine as producing a handicap in comparison with direct air cooling. I question whether actual temperature measurements would confirm this assumption. In either case, of course, we would consider that the design was such that all parts of the inside cylinder-wall were uniformly cooled, whether directly or indirectly.

The transfer of heat from the gas through the metal into the water is controlled almost exclusively by the transfer from the gas to the metal, as the water will take up many times as great a quantity of heat per unit of surface. Similarly, with the radiator, the water will transfer to the metal many times more heat than can be absorbed by the air. The water in an engine jacket is, of course, merely a carrier and an exceedingly efficient one; so, in my opinion, assuming other things to be equal, the number of transfers of heat in the water-cooled engine does not enter into the problem.

Mr. Lawrance cites later the limitation of a water-cooled engine that the cooling medium boils at 212 deg. fahr. This is certainly a limitation at present, but I am anxious to see the development of a satisfactory cooling system using a liquid that boils at nearly 300 deg. and yet does not freeze at a temperature above 0 deg. fahr. Kerosene meets these requirements so nearly that I believe it would be widely used, provided the engine cooling-systems were designed with the idea of handling it.

A MEMBER: — How does Mr. Lawrance measure the cylinder temperature? Does he use a thermocouple? If so, what precaution did he take to measure the particular point in which he was interested? Was the cylinder shown in Fig. 13 of his paper an aluminum, an iron or a steel cylinder? Have any figures been compiled for the relative temperatures under corresponding conditions of an aluminum and a steel cylinder? What method did Captain Hallett use in measuring the temperatures of air-cooled cylinders?

MR. HERON:—The temperatures on the Airco cylinder given in Fig. 13 of Mr. Lawrance's paper were measured by platinum-iridium thermocouples of the contact variety. This type of couple measures point temperature and the accuracy is probably within minus 20 deg. fahr. on the head temperatures and minus 50 deg. fahr. on the barrel readings. The relative accuracy of head readings to each other, or barrel readings to each other, is within 20 deg. fahr.

Regarding the relative performance of steel and aluminum cylinders, no figures are known of such tests on cylinders of similar design. Tests were, however, carried out on cast-iron and aluminum cylinders of almost identical design to that shown in Fig. 8, but fitted with shrunk-in liners, such as are provided for in Fig. 7 of Mr. Lawrance's paper. The cast-iron cylinder, cast from the same pattern as that for the aluminum cylinder, developed the same brake mean effective pressure as the aluminum type, but on a 10-per cent higher specific fuel-consumption. Reference is made to a Resume of Experimental Work on Air-cooled Cylinders at the R.A.E., by A. H. Gibson, D.Sc.[8]

MR. LAWRANCE:—The information given in Fig. 13 of my paper was obtained from S. D. Heron of McCook Field. The cylinder shown in Fig. 13 has an aluminum head and a steel body. I am sorry to see any one so pessimistic as Mr. Crane is about the future of air-cooled engines. I believe he will modify his views in the course of time. I cannot agree with his statements regarding rugged simplicity. The simplicity of a crankshaft that has nine bearings as opposed to one having three does not appear very great; and water pipes that must be made so that the flow of water to each cylinder will be perfect, to cool the exhaust-valves of each cylinder properly, are not a simple matter either. What Mr. Crane says about single-cylinder water-cooled engine tests is perfectly true. With air-cooled engines it is not true. In an air-

[8] See *Advisory Committee for Aeronautics Report* No. 24.

cooled engine there will be just as good air-flow around the heads and valves of each cylinder, no matter what the number of cylinders may be. In the water-cooled engine, if the water pipes are not arranged right, or some eddy occurs in the flow, one cylinder will be overheating while another is cooling properly. For that reason a multi-cylinder water-cooled engine will not come up to the standard of a single-cylinder water-cooled engine.

Another point about these so-called fragile, delicate air-cooled engines is that, as has been said, a crew of men who are accustomed to handling those engines very rarely breaks even a fin, although this does occur occasionally. The most damage occurs where aviators run into things with a plane; generally, in that case, a water-cooled engine also suffers somewhat. If an Hispano-Suiza engine is dropped on the ground, the water-pump will generally break. They must be handled carefully. Of course, if a few cooling fins break off, it does not matter much, but, if the water-jacket is broken, within a few minutes the engine will not operate.

One can remove the cover from our nine-cylinder engine and take out the crankshaft by removing one cylinder and unbolting the master rod. Any cylinder and connecting-rod can be taken out without removing the crankcase from the airplane. The arrangement is such that one can clean the screens for the strainers through a very conveniently located hole at the bottom of the engine. It is not necessary to remove the carbureter to take the engine off the fuselage; it is necessary only to break the oil pipes and remove the bolts that hold the engine to the bulkhead. Those who investigate modern air-cooled engines will find that they are rugged, simple and easy to maintain.

MR. MEAD:—What is the necessity of temperature control of air-cooled cylinders in flight?

MR. HERON:—The necessity of temperature control of air-cooled aircraft engines has yet to be proved, at least as applied to the cylinders. Efficient air-cooled cylinders will operate satisfactorily over a wide range of temperature. Maintenance of more or less constant carbureter-temperature conditions is undoubtedly desirable and in this connection Captain Hallett has suggested that carbureters be situated in the airblast, so that they will always be cold and thus adjusted for opening-up after a steep dive. The need of temperature control of an air-cooled engine is much less marked than that of a water-cooled engine. Overheating does not result in a loss of cooling medium; and a steep dive, though it makes the engine so cold that it will not open-up, does not result in damage from freezing.

Mr. Mead has raised the question of breakage of valves and springs on air-cooled engines which results from the excessive tappet-clearance developed when hot. There is no doubt that much trouble is caused by excessive clearances but, in my experience, wear rather than breakage is the usual result. It must be admitted that the valve-gear of the average air-cooled aircraft-engine cylinder is very crude. Open gears with poor lubrication and developing large tappet-clearance are not in any way on a par with high-class water-cooled-engine practice; compensating devices to secure constant tappet-clearance, whether the engine is hot or cold, overcome only one of the defects of open gears. Completely enclosing and lubricating the valves, springs, rockers and push-rods largely eliminates shock and wear and insures lubrication. The push-rods become heated, with the result that the clearance can be maintained practically constant. Maintenance of a constant clearance is of importance in avoiding an excessive change of valve-timing. Most air-cooled aircraft engines have heavily overlapped, hot-valve timing. and a large change of clearance results in an increase of an initially large overlap, usually causing the engine to start and idle poorly, and to tend to pop-back when the throttle is opened.

GOVERNMENT AID FOR AVIATION[1]

THE fundamental fault with the subsidization of air transport in Europe is that the subsidy is granted almost entirely for military reasons. It is essentially a premium on mere operation, for the most part. When new designs are encouraged, stress is put upon the military features. This is a vicious system inherently, because it is self-perpetuating; it discourages the only kind of development that can put aviation on its own feet. The European methods have been conspicuously successful for the purpose intended, but the American people has a very just suspicion on any kind of regular subsidy. I voice the majority opinion of aircraft men themselves by saying that we do not want any subsidy for the operation of aircraft in America. We do not want an industry that must be continually nursed to keep it alive. If that is the kind of business we are pushing, it does not deserve any help. But, while we may feel that some of the foreign governments are too paternalistic, we should not sit and do nothing. Our railroads never could have developed without Government cooperation. We can do at least as much for aviation.

I hardly need mention the main essentials, on which all seems to be in agreement. Some form of central governmental bureau for civilian aeronautics, such as is provided for in the Wadsworth-Hicks bill, is the most natural starting-point. Public confidence, safety of operation, the financing of new undertakings, the laying out of routes and a proper basis for insurance will all be facilitated greatly by proper Government cooperation. Let other nations back commercial aviation for its military value. If we can develop its real commercial value, military considerations will take care of themselves. A self-supporting going industry that is an economic asset to the Country is the best military asset as well. To attain this, the most serious problems at present are those of a technical nature, and these are involved almost without any exceptions in the design of the machines themselves.

France is spending $2,500,000 per year on aircraft subsidies that show every indication of being perpetual. Suppose our own Government should set aside, once and for all, one-fifth of this amount, and divide it into a series of prizes for the best new designs to accomplish the objects of safety for passengers, economy for merchandise and mail, and night flying. There is every reason to believe that, if this were done properly, the personal risk could be cut down to one-twentieth of its present value, little though it now is; that mail could be carried for a cost per pound of one-thirtieth of the present rates, successful though our air mail already is; and that aerial transportation would open up a great new field of its own not injuring present transportation systems, but supplementing them to the great advantage of the entire public.

[1] From an address before the Metropolitan Section, by Ralph H. Upson, airship designer and balloonist.

MOTOR FUEL FROM COAL

WHILE the problem of an adequate supply of liquid fuels is becoming more urgent in this Country, it may be of interest to consider how the same problem is being attacked in England where there is no natural supply of liquid fuel whatever exclusive of shale oil.

An article on The National Significance of Low-Temperature Carbonization, by David Brownlie, in the Feb. 3, 1922, number of *Engineering* (London) discusses at some length the recent developments in the production of liquid fuels and other important products by the low-temperature distillation of coal. This project was given impetus in England during the war by a keen realization of the absolute dependence of the country on outside sources of fuel for the navy, as well as for motor transport and for aviation. A systematic cooperative program of research was organized under the Department of Scientific and Industrial Research with a view to solving the technical difficulties in the production of a maximum amount of liquid fuel from coal.

The article referred to above indicates that at least some of the more serious technical problems have been solved, as well as the economic problem of a market for the products of the process. The conclusions are based on the results obtained in a plant operating on a commercial basis treating 36 tons of coal per day. This plant was described in detail in the Oct. 28, 1921 number of *Engineering*.

Mr. Brownlie gives the figures presented in Table 1 for the products of low-temperature distillates as compared with other methods.

TABLE 1—PRODUCTS FROM 1 GROSS TON OF AVERAGE COAL

	Low-Temperature Distillation	High-Temperature Distillation Gas Works	Coke Ovens
Temperature of Distillation, deg. fahr.	1,000	1,800[a]	1,800[a]
Solid Product (Coal Substitutes), lb.	1,624	1,512	1,568
Nature of Product	Smokeless Fuel Coalite	Soft Coke	Hard Metallurgical Coke
Volatility of Product, per cent	0.9	1.0	0.5[b]
Liquid Product (Motor Fuel, Fuel Oil, etc.), gal.	20[c]	10	8
Nature of Product	Coalite Oil	Coal Tar	Coal Tar
Gas, cu. ft.	6,000	12,000	11,500
Calorific Value of Gas, B.t.u. per cu. ft.	700–750	550	450
Sulphate of Ammonia, lb.	15	25	28

[a] Approximate.
[b] Maximum.
[c] Including 3 gal. of motor fuel.

Mr. Brownlie points out that at present there are used in Great Britain some 140,000,000 tons of coal that could be subjected to low-temperature distillation without including that used for gas production, metallurgical coke, and similar purposes, and that the treating of this coal would produce 400,000,000 gal. of high-grade motor fuel or twice the *present consumption;* also 2,350,000,000 gal. of oil, at least 50 per cent of which would be high-grade Diesel engine fuel, and from which could be produced an adequate supply of lubricants.

This would seem to meet the present demands for all liquid fuels in Great Britain. But an equally important feature of the process is the utilization of the non-volatile residue or coke produced. The product produced by this particular process, which is termed "coalite," is said to have all the desirable qualities of coal for practically all purposes. It has the advantage of being smokeless, having only about 10 per cent volatile matter, and the author discusses at considerable length the smoke evil that might be eliminated by the universal use of this fuel. Another advantage of it is that it gives a much higher *radiant* efficiency in open grates, some 10,000,000 of which are in use in England.

A discussion is given also of the advantage of the increased production of sulphate of ammonia that would attend the general adoption of low-temperature distillation practice and could be used to increase the agricultural production of the country.

While the article seems to show conclusively the technical practicability of meeting the present fuel needs of Great Britain from the coal resources alone, and of eliminating smoke, promoting agriculture and affording a better fuel for open grates, there is no discussion of the relative cost of meeting the situation in this way as compared with the present practice of importing liquid fuels.

CORROSION OF CHROMIUM STEELS

IT appears from the series of tests that the Bureau of Standards has carried out upon the corrosion of chromium steel that the behavior of the material when subjected to the acid test is not a sure criterion of its resistance to atmospheric corrosion. Of all the alloys examined, a high nickel-chromium steel, invar, pure iron and medium carbon-steel that cooled very slowly from a high temperature were the most resistant to hydrochloric acid as measured by the loss of weight per unit area per day. High-chromium steels, for example, 13.70 per cent of Cr, 0.29 per cent of C, were found to be attacked by acid very much more readily. However, when the same specimens were subjected to a weathering test, consisting of a partial immersion in water and exposure to the air, the order of resistance was almost completely reversed. The high-chromium steels were the ones to withstand the treatment best, the low-chromium ones and the pure iron showing rust spots early in the test. The combination of both nickel and chromium appears to make the steel resistant to both acid and weather attack. In general, the steels that were quenched were found to resist corrosion better than the same material in the annealed state, but the differences found were much less than the differences resulting from composition changes, thus indicating that composition rather than treatment should receive the first consideration.

OXYGEN IN IRON

A SERIES of melts of electrolytic iron have been made at the Bureau of Standards under air in the induction furnace with additions of varying amounts of metallic calcium as a deoxidizing agent. The addition of calcium up to 0.2 per cent did not increase the soundness of the chilled cast ingots. The amount of oxygen, as determined by the Ledebur method, in the ingots was practically the same throughout the series, regardless of the amounts of calcium added. The average oxygen-content of the calcium-treated melts was approximately 0.23 per cent. Pure electrolytic iron melted under the same conditions contained 0.21 per cent of oxygen. All the above-mentioned melts were made in the open under still air. Electrolytic iron melted under a jet of air contained only slightly more oxygen than when melted under quiet air, namely, 0.24 per cent. Ingot iron melted under similar conditions under quiet air and under an air jet contained, respectively, 0.21 and 0.26 per cent of oxygen. Ingot iron melted under the oxidizing flame of a gas blast-torch contained 0.26 per cent of oxygen, the same as when melted under a jet of air.

Economics of Motor Transport

By MERRILL C. HORINE[1]

ANNUAL MEETING PAPER — *Illustrated with* PHOTOGRAPHS AND DIAGRAM

THE author states that motor transport today is threatened with arrested progress due to the lack of economic coordination between motor-vehicle operation, highway construction and legislative regulation. Highways constructed at considerable cost to the public have gone to pieces everywhere, in many cases years before their bond issues have matured. Efforts to preserve these roads have been confined principally to heavy taxation and restriction of motor transport; they have not been made upon a sound economic basis, largely because principles of highway-transport economics are not only imperfectly understood, but have hardly been studied sufficiently to provide any definite basis of understanding. The development of highway construction and motor-truck operation must proceed along sound lines to protect the public against serious and unnecessary losses, to preserve what highways we have, and to build a foundation for better ones in the future and to forestall disaster to the builders and the thousands of users of the most economical types of highway-transport vehicle. The solution of this matter is the application of scientific inquiry and engineering skill to the economic problems presented. As a contribution to preliminary thought on the subject, this paper was prepared for the purpose, principally, of stating the main features of the problems involved in their interrelation and significance.

An effort has been made to represent graphically the factors entering into the ideal of motor-transport economics; namely, economic efficiency. The conclusions hazarded in the paper are suggestive rather than final in many cases and no attempt has been made to evaluate definitely the various factors of efficient motor transport. It is hoped that the paper will provoke thought and discussion among engineers, to the end that the considerable volume of research necessary to arrive at such evaluation can be promoted.

IT would be absurd to state that the engineering development of motor-truck and highway-tractor design is at an end or that, even in the face of the greatest economic emergency, it should be halted; but the time has come when the engineer must turn his scientific inquiry and deduction into other and equally important channels. The development of the motor truck has placed it in a position of economic and industrial importance that demands the application of engineering to the broader aspects of motor transport. The highway, which until the development of the railroad was the chief factor in the economic and military progress of nations, is once more taking its place as the most important factor in transportation. First the war, then the railroad demoralization that followed it and lately the threatened railroad strike, demonstrated the emergency value of motor transport in industrial life, and in commerce.

It is not generally known or even suspected by the great mass of people that the motor truck is today transporting approximately one-eighth of the tonnage transported annually by all of the railroads in this Country. Motor trucks transport approximately 300,000,000 tons as against about 2,400,000,000 tons transported on rails. Yet, of the 2,000,000 miles of highway in this Country, only about 12 per cent or 300,000 miles is improved. Motor-truck operation is confined principally to this 300,000 miles, which is 20 per cent more than the 250,000 miles of railroad in the United States. Authorities have been predicting for years that, despite the tremendous size and importance of the passenger-automobile industry, the motor-truck business is destined before long to exceed it in size.

The development of the motor truck has been so rapid that highway development has by no means kept pace with it; in fact, highway development lags far behind the requirements for passenger automobiles. It can be said truthfully that modern types of road pavement are the outgrowth of motor-car development, but there is evidence on every hand that the majority of so-called motor-vehicle roads are not adapted to motor trucks.

Until recently, what little scientific research there was in respect to motor transport centered about the economy of the vehicle itself, while that devoted to highways took little or no account of the most economical types of motor truck. Such narrow conceptions inevitably lead to uneconomic conclusions. The student of vehicle efficiency alone soon finds that the larger the vehicle is and, consequently, the greater the useful load that it moves, the more economical in cost per unit of load it will be. The highway engineer, on the contrary, reaches the conclusion that the most economical road is one of light construction, narrow width and general conformity to the topography of the country. The vehicle economist therefore urges trucks of the greatest capacity that can be operated conveniently and for which there is sufficient load to carry, and the highway engineer urges nothing but the lighest of vehicles. The result is a compromise which is neither scientific nor economic, since, as a rule, the actual roads are of insufficient strength and durability to withstand the exactions of prevailing traffic, and the average vehicle is too small to produce the haulage economy which is needed. Vast sums are squandered annually on types of road utterly incapable of returning in traffic facility and durability enough value to justify their cost, and the public is obliged to pay, in the cost of commodities, an unduly high transportation-cost because of bad roads, poorly adapted routes and unreasonable restrictions upon weight and speed.

Coordination between highway and vehicle development is difficult because of the independent control of vehicle operation and of road building, but it is impeded still further by the lack of understanding that exists as between the highway authorities and motor-truck operators, and by the confusion of issues by the general public. The problem of the railroads has been very much simpler, since those charged with maintenance of way and those responsible for the operation of rolling stock move under the control of a single directing management, the engineering activity of all branches of the enterprise being consolidated and coordinated. The result has been the development of locomotives and cars capable

[1] M.S.A.E.—Engineer, International Motor Co., New York City.

FIG. 1—HIGHWAYS MUST BE DEVELOPED IN CONJUNCTION WITH VEHICLE PROGRESS

Railroad Development Was Not Retarded by the Existence of Iron Strap Rails for Such Trains as Were Drawn by the DeWitt Clinton, but Has Kept Pace with the Increase in the Weight and the Speed of the Rolling Stock

of moving 5000 tons in one traffic unit, and of roadbeds and rails capable of supporting such loads at economical speeds. The engineering work devoted to the development of the railroad grade, track, bridges and other works included in the right-of-way has required a degree of intensive study not inferior to that directed toward the perfection of the rolling stock.

Coincident with this work, economic engineering of the highest order has been necessary to coordinate the development of the two so that the result would be conducive to the most economical transportation. Independent work by either the civil or the mechanical branches of railroad engineering could never have reached the point that they have attained in conjunction, as indicated in Fig. 1. Likewise, highway and vehicle engineers can never develop highway transport to its ultimate efficiency without coordinating their activities.

Legislation enacted independently by the 48 little republics that constitute this Nation cannot do otherwise than increase the economic loss resulting from the mutual unadaptability of the motor truck and the highway, as indicated in Fig. 2. The railroads were the target for restrictive attention by legislators not so very long ago, and it is admitted universally today that legislative meddling with the railroads has not been conducive to increased efficiency, lower charges to the shipper or industrial peace. Hundreds of official inquiries into the cost of living have been unavailing, and the economist's voice in the wilderness pointing to the deep underlying causes is still unheard.

The success of the automotive industry depends upon the degree of utility of its products to the public. Anything that detracts from the utility of the motor truck threatens the welfare of every member of the automotive industry. There is nothing that has so profound an effect upon prosperity as transportation. All industry exists as a result of an unequal distribution of commodities geographically, and consists of the production of a surplus where such production can be carried on most economically to supply a deficiency at some other location. The history of any manufactured article is a history of a long journey; in many and perhaps in most cases the cost of development represents the greater part of its cost.

FIG. 2—INDISCRIMINATELY LEGISLATING THE MOST ECONOMICAL CARRIERS, THE BIG TRUCKS, OFF THE HIGHWAYS, CITY STREETS AND COUNTRY ROADS IS AN ECONOMIC WASTE; HIGHWAYS SHOULD BE BUILT TO CARRY THE BIG TRUCKS

While the Cause of This Action Is the Inability of Some of the Poorer Roads To Withstand Modern Traffic, Such a Practice Increases the Cost of Transportation and the Latent Value of Good Roads Is Not Realized

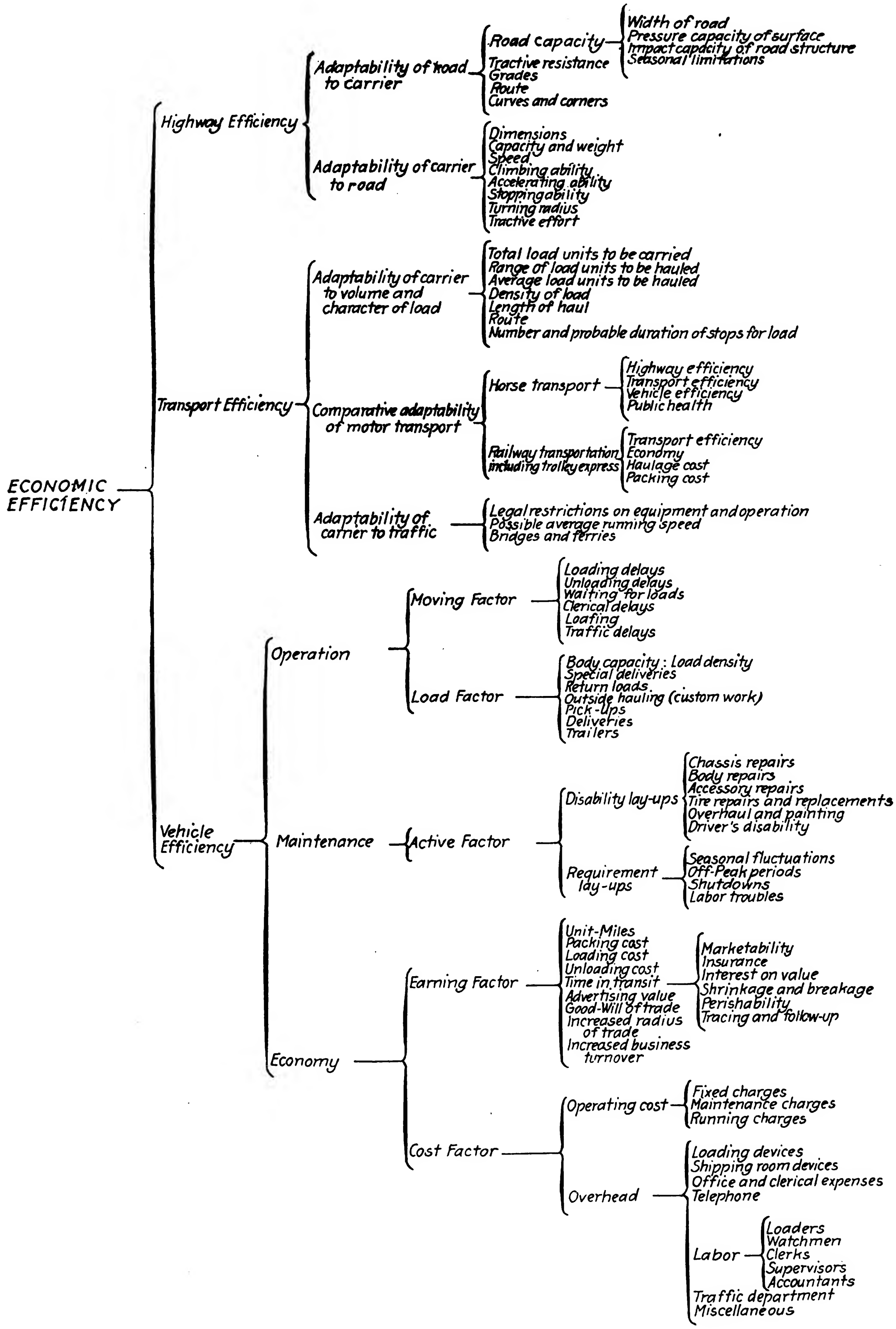


Fig. 3—Chart Showing the Economic Efficiency Factors of Motor Transport

Motor-transport economics, therefore, represents the means whereby the public can be enabled to derive more benefit from the product of the automotive industry, and involves the scientific study of all factors relating to the transportation of loads over roads. The study of motor-transport economics calls for engineering, both civil and mechanical, the principles of which are common and combine considerations of mechanical efficiency, road structure and commercial traffic. It contemplates highway transport in relation to the interests of the public as a whole.

Fig. 3 is an outline of the principal elements of the subject in their intricate relation. Each element is combined with related elements to form a single factor. These factors, in combination with other related factors, are reduced to terms whereby a balance can be secured between antagonistic considerations to make up a coherent conception of their interrelation. For lack of precedent, arbitrary terms have been used to designate the various factors and groups of factors. The entire subject has been reduced to a single term, that of "economic efficiency."

Economic Efficiency

Economic efficiency, as related to highway transport, can be defined as the measure of net benefit derived by the community arising from the operation of a motor-transport installation.

We of the automotive industry must get into the habit of thinking of motor-transport economy in the terms of cost to the consumer. We cannot hope to have the strong, hard, smooth, wide highways, connecting industrial centers by direct routes, which we know are essential to the proper and continued expansion of the motor-truck industry, before the public shall have been convinced that the cost of such roads is merely an investment in cheap transportation that will be returned with interest in the form of lower commodity-prices by reason thereof. The highway industries must likewise revise their conception of the motor vehicle, and particularly of the motor truck, from that of a trespasser on the roads to that of an essential and economical carrier capable of earning its share of the cost of roads capable of accommodating it. They must be brought to realize that the highway exists for the benefit of the vehicle, that its usefulness consists of its ability to serve the vehicle, and that its economic justification is the saving in transportation cost that it enables the vehicle to effect.

Finally, the general public must realize its position as a stockholder in every transportation enterprise. Public investment in highways pays dividends in the form of lower transport-costs than would prevail without them, and in proportion to the extent to which highways and vehicles are adapted, on the one hand, and the extent to which this adaptability permits the operation of the most economic types and sizes of motor truck and methods of operation, on the other hand. Taxation of motor trucks out of all proportion to the benefits derived from their operation does not shift the burden from the commonwealth to the private pocket of the truck owner, but simply requires that highway cost be paid in the form of increased cost of commodities instead of in taxes, with the constant danger that the continual readjustment of charges for haulage and commodities hauled by motor-truck users will result in waste and commercial losses, including the retardation of motor-transport development; all of which reacts unfavorably on the public purse.

FIG. 4—SCRAPPING THE BIG TRUCK WILL NOT DECREASE THE AMOUNT OF GOODS TO BE MOVED
This May Increase the Burden on the Community Instead of Effecting a Saving, Since a Larger Number of Smaller and Less Economical Trucks Must Be Employed

Restriction of sizes and weights of truck for the purpose of prolonging the life of uneconomic types of road, such as to prevent the operation of the most economical type and size of truck, will prove expensive to the public in the end for two principal reasons

(1) The elimination of the heavy truck will not reduce the volume of transportation over the road, but will divert it to smaller vehicles in greater number; this will occasion a considerably higher transportation-cost, as is illustrated in Fig. 4

(2) The operation of this greater number of smaller vehicles at higher speeds and generally greater impact upon the road will result in more rapid road-wear and will require, in time, the widening of the road to accommodate the large number of vehicles. The cost of a wider road of lighter construction may very possibly be greater than that of a narrower one of heavier construction, as is shown in Fig. 5

The maximum economic efficiency, therefore, depends upon the adaptability of the road to a type of vehicle that is the most adaptable to the nature of the haulage work

FIG. 5—LIGHT-TYPE ROADS ARE NOT NECESSARILY MORE ECONOMICAL TO BUILD THAN STRONG ONES
Restricting the Traffic to Small Vehicles Means Multiplying Their Number and Hence a Greater Width of Road Is Required for Their Accommodation

to be performed, operated in the most effective and economical manner. These considerations involve three groups of factors which can be termed highway efficiency, transport efficiency and vehicle efficiency.

HIGHWAY EFFICIENCY

Highway efficiency consists of (*a*), the adaptability of the road to the carrier and (*b*), the adaptability of the carrier to the road. In other words, a highway may be efficient by reason of its appropriateness to prevailing types of vehicle or because the vehicles are adapted to its particular construction, as is indicated in Fig. 6.

As shown in Fig. 3, the adaptability of the road to the carrier requires that it possess the proper capacity, tractive resistance, grades, routes, curves and corners; in other words, it must be wide enough to permit the traffic to flow freely and without unnecessary delay. What width will best accomplish this end will depend naturally upon the types of vehicle making up the traffic and the volume and speed of such traffic. It must have a surface capable of withstanding the pressure of the tires and a structure capable of withstanding the impact occasioned by the passage of the vehicles. It must be of such nature that the changes of condition with the seasons or weather will not interfere with its use. It must have a surface that produces a low tractive-resistance, grades that are within the practical ability of the truck and a route calculated to give direct and easy access to the points that the truck must reach. Curves and corners must be such as to permit the vehicle to negotiate turns without difficulty. The adaptability of the carrier to the road naturally depends upon characteristics of ability complementary to the above-specified elements.

A road that is narrow, soft and poorly drained, having steep grades and sharp curves, is naturally very poorly adapted to heavy tractors and trailers, the characteristics of which require a road of at least 16-ft. width having a smooth, hard surface, a firm subgrade, good drainage, moderate grades and gradual curves wider than the straight portions of the road.

TRANSPORT EFFICIENCY

Transport efficiency consists of (*a*), the adaptability of the carrier to the volume and character of the load, (*b*) the comparative adaptability of motor transport to horse transport or railroad transportation and (*c*), the adaptability of carrier to traffic conditions.

Again, as shown in Fig. 3, the adaptability of the carrier to the volume and character of load depends upon the total load-units to be carried, the range as constituted by the maximum and minimum load-units to be hauled per unit of time, the average load-units per unit of time, the density of the load, the length of haul and its route and the number and probable duration of stops for load.

By the term load-unit is meant the unit by which the load is measured; such as tons for coal, cubic yards for

FIG. 6—THE RESTRICTION OF TRUCK SIZE WITHOUT ANY RESTRICTION ON THE LOAD WILL NOT ADEQUATELY PROTECT ROADS THAT ARE NOT STRONG ENOUGH TO MEET THE TRAFFIC REQUIREMENTS
The Restriction of Truck Size Encourages Overloading. Overloaded Light Trucks May Be More Destructive Than Properly Loaded Heavier Vehicles and Are Also Dangerous

sand, gallons for oil, thousands of board-feet for lumber, packages for department stores and cans for milk. The character of load-unit and the kind of material or commodity that it represents determines the type of body best adapted to efficient haulage; and the maximum, minimum, average and total amounts to be hauled, together with the length of haul, determine the most economical size of chassis. The route and the number and probable duration of stops for load have a considerable bearing upon the type of equipment that is most economical; that is, whether a truck, a tractor with semi-trailer, a truck with full trailer or a tractor and trailer train is most suitable; whether solid or pneumatic-tire equipment should be provided; and whether gasoline or electric power should be used.

If the work involves a long haul over a route including soft and tortuous mountain-roads, with few stops of short duration, the material being in units of packages of low density, the equipment is limited immediately to a light-weight, high-speed pneumatic-tired chassis having an enclosed or a screen-sided panel-body equipped with means for readily taking out individual deliveries. The equipment will naturally have to be gasoline-propelled, preferably provided with electric light but not necessarily with electric starting. If, on the other hand, the work involves the haulage of a large quantity of an exceedingly dense material of a non-fragile nature, in cubic-yard units over only a few miles of reasonably hard and level road, with no stops for loads between terminals and subject to considerable variation in the number of cubic yards to be transported per day, the most economical equipment is a 7½-ton chassis having a wide, flat, steel, mechanical-dumping body, with full trailers having similar bodies for use when the volume of work is particularly heavy.

The comparative adaptability of motor transport to other means of transportation depends upon the comparative adaptability of different possible methods along the line already stated. In the consideration of horse transport, practically every factor concerned with motor transport must be taken into account. In addition, the factor of public health will become more important. In connection with railroad transport, the comparison with motor transport is limited to consideration of transport efficiency and economy. Moreover, railroad transportation must be judged also from the standpoints of the cost, delay and breakage incident to carriage over the streets at each end of the rail haul, and the extra packing, boxing and carting required in railroad transportation. In most cases it is not difficult to define the separate fields of efficient transport of the horse, the railroad and the motor carrier. None of the three is capable of serving for all kinds of transportation efficiently. The field of motor transport lies in a ground between economical horse and railroad transportation. The adaptability of the carrier to traffic conditions depends upon how it conforms with State and local regulations, the average running speeds that are possible in prevailing traffic and the degree to which it is adapted to bridges and ferries on the route, as illustrated in Fig. 7.

Vehicle Efficiency

Vehicle efficiency is concerned with the comparative amount of benefit derived from the operation of the equipment for the amount of expense of one sort or another incurred by its operation, and can be expressed as the combination of effective operation, efficient maintenance and economy of cost.

Effective operation can be expressed as the combination of two factors; namely, the moving factor and the load factor. The former is simply the percentage of time spent by the truck in moving. The latter represents the percentage of load capacity that is constituted by the actual average load carried. Fig. 3 gives a few of the principal elements of operation that affect these factors. Thus, a truck can be considered to have a 100-per cent operating efficiency when the wheels are turning every minute of the working day and it is carrying a full-capacity load at all times. Such a condition could rarely exist, but it is conceivable that a truck might be used in spreading road material in such a manner that it would receive its load from a traveling chute without stopping at the loading point, and would spread it on a road or yard surface while moving through the unloading point. Ordinarily, a moving factor of 60, representing 6 hr. running out of a 10-hr. day, and a load factor of 50, representing a 2½-ton average load on a 5-ton truck, are to be considered satisfactory operation.

Maintenance efficiency is expressed by a single factor; namely, the active factor, by which is meant the percentage of working days during which the truck is in commission. An active factor of 100 per cent represents a truck in commission 310 working days in a 310-day year. Fig. 3 indicates two classes of lay-up that commonly are responsible for an active factor of less than 100 per cent; namely, those due to disability of the truck and those due to conditions in the owner's business that render the operation of the truck unnecessary. An active factor of 100 per cent is by no means uncommon among the better grades of chassis.

Economy, in the narrower sense in which it is used in connection with Fig. 3, consists simply of the ratio between cost and earning. These are termed, respectively, the earning factor and the cost factor. Included in the earnings of a motor truck are all the benefits that accrue to the user by reason of its operation, including the savings effected over what his costs would have been by the next most suitable form of transport. Fig. 3 only outlines and suggests a few of these benefits, which must of necessity be of limitless variety in different installations. The cost factor is made up of two groups of expense; namely, the operating cost and the overhead. Included in the operating cost are the usual fixed, maintenance and running charges, covered by the National Standard Truck Cost System, and under overhead are all other charges concerned with the business that arise from or are necessitated by the operation of motor transportation.

It is possible to derive some measure of the economic efficiency of a motor-transport installation out of a combination of all of these factors. These are the materials with which we have to work, the remaining problem in arriving at a conclusion being to evaluate and harmonize them in such a manner as to attain an equation in which all factors are in their proper proportion. To do this, it is first necessary by experiment, research and calculation to base as many of these factors as possible upon definite determination of facts, many of which are exceedingly obscure today. As might be expected, it is not possible within the limited compass of a single paper to more than reconnoiter the ground to be covered by a research development that it is hoped will enlist the co-operation of automotive and highway engineers and economists throughout the industry.

Lines of Necessary Research

Some of the principal subjects for needed research for the development of what can be termed the economics of

FIG. 7—LARGE-CAPACITY TRUCKS ARE BETTER ADAPTED TO CITY TRAFFIC CONDITIONS THAN SMALLER VEHICLES
The Obligatory Slow Speed Is Normal to the Large Truck and It Can Deliver Large Daily Tonnages Despite Traffic Conditions, and Since the Same Amount of Tonnage Can Be Transported in Fewer Vehicles There Is a Tendency Toward a Reduction in Traffic Congestion

motor transport are (*a*) highway engineering, (*b*) highway economics, (*c*) traffic investigation and (*d*) automotive engineering. In regard to highway engineering, they are

(1) Safe tire-loads for various types of road construction
(2) Safe total axle-weights for various types of road construction
(3) Impact resistance of various types of road construction
(4) Tractive resistance of various types of road
(5) Super-elevation of curves
(6) Relation of necessary widening of road at corners to degree of curvature
(7) Types of bridge appropriate to various types of road
(8) Necessary degree of surface smoothness to reduce impact to harmlessness

Under highway economics are included the

(1) Construction and maintenance cost per mile of various types of road, pro-rated over the life of the road
(2) Vehicle capacity of road per hour, under practical traffic conditions
(3) Tonnage capacity of road, with various types of traffic, in reference to the speed and capacity of trucks
(4) Proportion of highway and vehicle cost respectively to the total cost of motor transport

In traffic investigation, the need is for a traffic census on important street and highway motor-truck routes. Such an investigation should show not only the total number and types of vehicle traversing the road, but the load factor and speed under which they are operated and changes in volume at different periods of the day, all such data being collected at various times and at several points so that the following factors can be determined

(1) Daily tonnage hauled over the route
(2) Daily vehicle-mileage over the route
(3) Average load per vehicle
(4) Average miles traveled on the route per vehicle
(5) Ton-miles per day on the route
(6) Comparative ton-miles at different hours of the day and on different days of the week
(7) Comparative ton-mileage at different times of the year
(8) Comparative ton-mileage at different points of the route
(9) A study of comparative costs of transportation by railway freight, express and trolley express

Such a study should contemplate the complete cost for different classes of material commonly hauled on motor trucks, including freight charges, trucking at the point of origin and destination, and extra packing-costs.

Automotive-engineering research is desirable on the effect of grades, relative smoothness of surface and tractive resistance upon

FIG. 8—MOTOR TRUCKS MAKE POSSIBLE QUICK AND CHEAP MARKETING OF MANY COMMODITIES
Without Motor Trucks Crops, Milk, Livestock and Other Commodities Either Would Decay, Sour or Shrink in Transit or Else Necessitate Higher Retail Prices Resulting from Their Scarcity

(1) Gasoline consumption
(2) Speed
(3) Drawbar-pull
(4) Acceleration

Work along these lines is in progress. The Bureau of Public Roads of the Department of Agriculture is spending $150,000 per year on road research and experiment. The various States and the National Research Council also are vigorously prosecuting work along similar lines. The Iowa Engineering Experiment Station, for example, has $10,000 per year to spend upon highway research, of which it is understood about $7,500 will be devoted to an economic study of highways.

The National Research Council, through its Committee on Economic Theory of Highway Improvements, under the chairmanship of Prof. T. R. Agg, is conducting a series of tests at the Massachusetts Institute of Technology to determine some of the physical relationships between the vehicle and the highway.

Experiments begun by the Office of Public Roads, under the direction of A. T. Goldbeck, are being continued. Mr. Goldbeck, as chairman of the National Research Council's Committee on Structural Design of Roads, is making a new set of tests on the Illinois experimental highway.

The $275,000,000 Federal aid appropriation for highways has not been spent by any means. It is estimated that the annual highway expenditure of the Federal Government, the several States, and the counties and townships within those States, amounts to $1,000,000,000 per year. As against this, motor-vehicle owners contribute the largest single item, conservatively estimated at $316,720,878, of which $102,000,000 is in registration and license fees alone; and the amount being contributed by motor-vehicle users in the form of direct taxation is increasing rapidly.

There can be no doubt that the principle of taxing the users of the highway for the privilege of making use of the public roads is faulty, especially when the basis upon which the tax is levied is unscientific and inequitable, applying only to power-driven vehicles in most cases, while permitting animal-drawn vehicles free use of the highway. Unquestionably, the benefits of the highway extend to every citizen, irrespective of whether he operates a motor vehicle. This special taxation is inevitably passed along to the general public in the form of increased price of commodities, illustrated in Fig. 8. The practice is gaining impetus throughout the States. Texas has recently passed a law whereby motor trucks are taxed a certain amount per mile operated.

Acquiescence to this condition of affairs by motor-vehicle users carries with it the right to demand a voice in highway councils to the end that the money shall be spent on types of highway construction that are economically suited to the transportation needs of the Country. It is the engineers of this automotive industry who must lead in furthering the proper economic development of the highways and the development of motor-transport.

THE DISCUSSION

CHAIRMAN B. B. BACHMAN:—Mr. Horine has touched upon a very fertile subject for discussion. The question of highways in all its ramifications is one of the most important that the automotive engineer of today has before him. It is not a problem that can be compressed within narrow limits, and it has an uncanny faculty of intruding itself in the most unexpected manner. The need of the Country for roads is unquestioned. The possibilities in earning power of completed roads adequate for the transportation of the commodities of the Country, without infringing in any way upon the functions of the public-utility companies, are enormous. Whether the figures that Mr. Horine has given are correct or not, within even a relatively large percentage, appears to me to be comparatively unimportant. The figures are tremendous; but almost any figures may be assigned and still not touch the possibilities or describe the actualities.

There is no doubt that we are face to face with a very practical problem. How shall we finance the construction of these roads? How can we sell this idea to the public? As Mr. Horine has indicated, there are a number of serious errors crystallizing in the public mind. I am rather fearful that we of the automotive industry, as a class, have been somewhat to blame for these erroneous beliefs. I am somewhat apprehensive lest the possibilities of commercial advantage may have blinded us to the future. This is not only true in reference to the truck and its relation to the public, but with regard to traffic delays. It is not pleasant to drive down a street and be in one of the 20 or 30 vehicles behind a trolley-car that stops at a crossing. On the other hand, the pedestrian has as much right on a highway as the man in the automobile and, in most cases, he is considerably at a disadvantage. Congestion and delay are necessary to protect that man's rights. They are an economic waste, there is no question about that, but they must be overcome by constructive criticism and reasonable suggestion.

The paper Mr. Horine has given presents an excellent point of view. It is possible that there are some who differ from his opinions, but the function of these meetings is to bring out these differences and, by doing so, to attempt to formulate a policy that will overcome and correct the difficulties. This is the fundamental reason for our meeting.

R. E. PLIMPTON:—Mr. Horine has really discussed the scientific utilization of motor transport, rather than its economics. He says as much in the statement that the subject "involves the scientific study of all factors relating to the transportation of loads over roads." I make this point because it seems to me that the term economics had better be used in its generally accepted meaning, as relating to the financial aspects of the subject.

The use of the term efficiency is also to be questioned. It seems to refer to almost any of the divisions under which Mr. Horine considers the subject of motor transportation. This may seem to be mere quibbling about the meaning of words, but that this is not true is shown by Mr. Horine's definition of economic efficiency as the "measure of net benefit derived by the community arising from the operation of a motor-transport installation." It would seem preferable, particularly in a discussion before a body of engineers, to use this term as meaning the ratio of the total cost of operating a motor-transport system to the total revenue derived from it. Then we have an efficiency or ratio measuring performance, based upon economic units of dollars and cents. This efficiency, as thus defined, will become of greater importance as the art develops. The cost of operation will be known more accurately, and a comparison can be made even if it is not possible to calculate actual revenue, by using the income derived from motor-haulage by companies, railroads or other organizations making a business of furnishing transportation.

The same objection to the word efficiency applies to its use in other parts of the paper but not, of course, when it refers to a definite numerical ratio, as in Mr. Horine's discussion of effective operation and of maintenance effi-

ciency, better called effective maintenance. The explanation of the latter, however, states that it is expressed by a single factor, the percentage of working days the truck is actually in commission. This does not measure completely the effectiveness of the maintenance. Why not combine two factors, the percentage as proposed by Mr. Horine and one measuring the effectiveness of fuel consumption? The latter could be expressed as the ratio of fuel actually used during the working year to the amount that would be used were the truck always in the best operating condition.

The carrying of "live" freight has not been considered in the paper, although such service is one of the most important which now makes use of automotive equipment. It has been well said that passengers are only freight that is self-sorting and self-handling. The motorbus of the present, or at least the type now used by responsible companies in regular service, is built ordinarily on a motor-truck chassis; consequently, its economics and utilization are properly to be considered in any discussion of motor transport. The motorbus of the future probably will be a special type of truck, with provision for higher speed, better riding qualities and lower floor-level than the vehicles designed for freight service. G. A. Green, of the Fifth Avenue Coach Co., said in his paper on Motorbus Transportation[1] that the motorbus should be a development of the passenger-car chassis.

A vehicle carrying both freight and passengers is likely to be in demand in sparsely settled districts. Table 1 is presented to show how far this movement has developed in California, where the roads and climate are good and the communities are scattered widely. The data in the table are based upon reports from 773 companies authorized to do business in California.[2]

TABLE 1—ANALYSIS OF BUS OPERATION IN CALIFORNIA

	Companies	Per Cent
Passenger	425	55.0
Freight	117	22.8
Passenger and Freight	97	12.4
Passenger and Express	11	1.4
Freight and Express	7	0.9
Passenger, Express and Freight	6	0.9
Freight, Milk	18	2.3
Freight, Milk by Contract	1	0.1
Parcel Delivery and Passengers	1	0.1
Freight, by Contract	6	0.9
Special Freight	6	0.9
No Data Given	18	2.3
Total	773	100.0

Summarized, Table 1 shows that 55 per cent of these companies are carrying passengers and 14.8 per cent passengers and freight; 27.9 per cent carry nothing but freight. This is not the place to discuss the subject in detail, but it may be said that the motorbus is already setting the pace for the scientific utilization of motor transport. There are several reasons for this. Motorbus operators make a business of transportation and in many States they are required to submit complete and accurate costs of operation. Effective operation is essential if they are to conduct their business at even a fair profit.

Mr. Horine's paper forcefully reveals the fact that we are approaching the third phase of the automotive industry. The first phase, with its construction problems, and the second phase, with its development of selling methods and channels, are now accompanied by a third phase in which the problems of utilization are being studied thoroughly.

M. C. Horine:—Concerning Mr. Plimpton's criticism of the term "economic efficiency," I supposed that it would be understood to mean the economic efficiency of highway transport and not interpreted broadly. Mr. Plimpton objects to that term as being broader than the definition, and proposes that we should confine it more to matters of cost and income. This seems to me to narrow it. I thought I made it broad enough when I said that it was a measure of net benefit derived by the community arising from the operation of motor transport. This includes not only cost, but many other broader considerations.

I am sorry Mr. Plimpton and I do not define efficiency alike. I have called it the "measure of net benefit"; Mr. Plimpton prefers: "the ratio of the total cost of operating a motor-transport installation to the total revenue derived." Referring to the chart in Fig. 3, we find that what Mr. Plimpton has defined is vehicle efficiency and not economic efficiency. In either case, however, Mr. Plimpton and I evidently agree as to the meaning of the word, differing only in its definition, since the ratio of cost to income, as it refers to efficiency in a commercial sense, like the ratio of input to output, which is the accepted definition of mechanical efficiency, is certainly a measure of net benefit. Throughout the chart in Fig. 3 I have confined my use of the word efficiency to items involving ratios between income and outgo.

Mr. Plimpton misquotes the chart in Fig. 3 when he refers to "maintenance efficiency," for it refers to this item merely as "maintenance," although it might be called "effectiveness of maintenance." It is not an expression of efficiency, but must be combined with "operation" or operating effectiveness and "economy" to produce "vehicle efficiency." I confess I cannot follow Mr. Plimpton in his proposal for an additional factor under "maintenance" concerning gasoline mileage. Surely effective maintenance produces other benefits than gasoline economy; if the latter is given special consideration, such things as repairs, depreciation, tire economy and the like should be included also. That is the reason for using the factor "economy." Gasoline mileage is purely a matter of economy and, because the effectiveness of maintenance reacts upon economy, they are considered as coordinate factors of vehicle efficiency. Another reason is that, since maintenance is expensive, this expense must be justified in some manner other than low cost or effective operation, because the cheapest maintenance would be to lay the truck up altogether, occasioning no expense for repairs, overhaul or inspection. The effectiveness of maintenance is therefore measured by the "active factor," or ratio of days in commission to days when operation is possible.

Motorbus transportation has not been considered in this paper because I felt that the term "transport" refers more to freight transportation than to passenger traffic and because Walter Jackson had been scheduled to cover the subject at this session in a separate paper entitled The Past, Present and Future of the Motor-Omnibus.

A Member:—What are the savings that might be effected with a truck over a good road as compared with the cost over a poor road? Consider a hard-surfaced road as compared with a macadam road that is badly cut up.

Mr. Horine:—That is a very important question. It is being investigated by the Massachusetts Institute of Technology. It is also under consideration by the Na-

[1] See The Journal, July, 1920, p. 67.
[2] See *Bus Transportation*, January, 1922, p. 27.

tional Research Council. Some very deep studies are being made along that line, but time is required to complete them. They are not yet complete. Various figures have been obtained on the resistance to traction of various types of pavement. Different authorities give a very great disparity of data on roads of the same description. That is the condition that prevents giving a categorical answer to the question at present. Undoubtedly, the great amount of research that is being done now along that line will develop some very definite figures.

A MEMBER:—Was this California experiment more of a road test than a mechanical truck test?

MR. HORINE:—The California test was entirely a test of a particular type of concrete road.

A MEMBER:—It seems to me that the question is one of relative efficiency of tires and surface. So far as the smooth surface is concerned, a hard smooth type will give the most efficient service. The history of the automobile industry, so far as passenger service is concerned, bears out the conclusion that a pneumatic tire gives the most efficient service. It gives a higher speed at less cost than any other type of tire ever put on wheels. So far as the point made by Mr. Horine is concerned, the impact of the pneumatic tire is much the same as that of the solid tire. It seems obvious to me that, where a cushion is created between the load and the surface over which it travels, one that is readily receptive of inequalities in the surface, this is, in effect, carrying the good road along with the vehicle, as has been argued for years in the pneumatic-tire industry. This is a fact and has been proved in thousands of instances in my own experience where, under what we call the rolling-resistance test, the same vehicle with the same load, when moved by gravity only, will register a difference in the amount of work performed as high as 100 per cent over other types of tire. Pneumatic tires are more efficient than solid tires. A cord tire will run from 40 to 60 per cent more efficiently in a purely rolling test than a canvas tire. The efficiency of a pneumatic tire is dependent upon the angle at which the tension members are laid with the tire, the air pressure that carries the load and the area of the tire that is brought into contact with the surface of the roads over which it travels.

It seems to me that urban and suburban passenger traffic ultimately could be moved on air just as well. We are only at the beginning of pneumatic-tire development. I believe firmly, after 30 years of experience, that we will be able to carry on air tires not only the maximum load of today, about 5000 lb. per wheel, but 10,000 lb. per wheel; and at a pressure not to exceed 50 to 60 lb. per sq. in. In fact, the limitation lies only in the size of the wheel that the automobile companies permit us to make. Therefore, I think my experience warrants me in saying that the future of the pneumatic tire for heavy duty is but beginning.

W. P. KENNEDY:—I believe that sometimes we gain an advantage by standing off and looking at our problems from a distance, rather than from our close position when we are engrossed with the details and are not able to discern all the possibilities of their solution. We can then assume a radical viewpoint. Mr. Horine's paper is primarily for the purpose of stimulating education in several directions, so that we can avoid the impediments or incumbrances that are likely to be imposed on the development of the automobile truck. There is evidently a vast need for education; in the direction of legislation, in the direction of motor-vehicle usage, and possibly in the direction of aiding the road-builders in solving their problems.

If we first consider the motor truck and ask ourselves what difference will exist between the present form and the future form in 25 years, a number of speculations arise. I agree that, in time, we will operate motor vehicles entirely on pneumatic tires. As we look at the truck now, there are two things that are fundamentally wrong with it; one is the mode of suspension and the other is the tire equipment, with reference to the work that must be performed by the truck. When a large truck is unloaded and operating in the street over a rough surface, we can imagine the energy that is being lost in raising the load over the obstructions of the street surface. We can get a fair vision of this when we ride behind a city taxicab of very light weight and notice that when the body is loaded it will remain practically in a horizontal plane and the axles will rise and fall with the impact of the road. If we could provide for motor trucks to function in that way, we would have an ideal condition. That condition probably can be approached by some form of progressive spring equipment that will take care of light as well as heavy loads. In a 5-ton truck operating empty, one might as well have cast-iron blocks in place of the springs, because the springs do not function at all; but if the truck had progressive spring equipment, the body would remain stationary with varying loads.

One of the steps that I think might be taken in the direction of equipping trucks ultimately with complete pneumatic equipment is to apply a dual equipment of a solid tire and a pneumatic tire side-by-side that would permit the solid tire to function when the pneumatic-tire load is exceeded. Progressive spring equipment could be furnished by combinations or auxiliaries that will be obvious to any good designer.

Looking again at our present procedure in the design of trucks, is it not reasonable to assume that there is considerable waste at present in that so many companies are building such varied lines of machines? Could not our present transportation requirements be fulfilled adequately by probably three sizes of motor vehicle? In the first size I would include those up to 1000-lb. capacity. Let the builders that are disposed to produce this line, largely from passenger-car equipment, construct the varied equipment that is at present on the market. The next is about a 2-ton size that would perform all the requirements that are necessary in cities. Let this 2-ton truck have an overload capacity up to 3 tons. For heavy work provide a truck that would nominally have a 5-ton capacity, but an overload capacity up to 6 or 7 tons with the necessary spring and axle modifications. The idea I have in mind is that, if the industry were concentrated upon these three sizes, great economics would be effected in the manufacture of parts, in the production of the machines, in the regulation of taxes and in the many other things that so complicate the question now, imposing as they do much waste and expense of which pioneers in the use of motor transportation must bear the burden. If it were thus possible to standardize upon the two larger sets of equipment, one in the 2-ton field and the other in the 5-ton field, and to allow those who are building light vehicles to include passenger chassis or anything else that they are disposed to use, much of the waste now existing in manufacturing tool equipment, selling effort and many other phases of the proposition would disappear.

With reference to educating business men in regard to the value of the motor truck, this frequently is difficult. The city users of the motor truck, as a whole, usually have been unaware of the cost of operation and, often, a user does not want to know or be worried with it. In

some cases he thinks he knows what his expense is but, when told that it costs more per year to operate a given size of machine than the truck originally cost him, he does not believe it. When he pays $5,000 for a truck and later learns that it costs him $6,000 per year to run it and that, in the 5-year life of the machine, its service costs him $30,000, he believes there is something wrong somewhere.

Methods of Road Construction

It was pointed out in the previous discussion that, if we could do anything to aid the Society in the general development of the industry, it would be welcome and proper for us to offer suggestions along that line. A thought or speculation about improved methods in the building of roads may be acceptable. It appears to me that there is considerable waste in the manner in which roads are built at present. First, it is a seasonable undertaking and there is only a limited time in the year during which work can be done. Roads are built in an ancient and crude manner; and, in so far as the handling of the material is concerned, there is practically no modern, scientific method in it.

Why would it not be possible to build our highways in the way we build our large office-buildings at present? The office building is built in a plant that has the tools and facilities for making the parts of the building most efficiently. Why would it not be a very desirable thing in the way of cost reduction to indicate to road-builders that at least the surface of the road might be built in a plant in relatively small unit-sections that would be convenient to transport? They could then have the proper mass-production equipment for doing it, they could work all the days of the year and the matter would resolve itself into satisfactorily producing the desired type of surface material and transporting the finished product to the point of application. The remainder of the work would consist in preparing the sub-surface with the use of modern machinery. Methods akin to railroad building might be employed with obvious improvements. Possibly an interlocking unit-surface could be supported as a bridge from side supports of poured concrete. This may appear like a dream but I venture to say that as we progress with the necessity of building a great mileage of the proper kind of roads, some such methods will be used. If such a plan were in existence, it would be possible to design a road scientifically for any given working capacity. Parts could be tested out in advance, they could be made to different specifications and the surface could be transported to the point of application with a remarkable reduction from the present ridiculously high figures for construction that are often questionable and sometimes a fraud.

Chairman Bachman:—The last two speakers have presented remarkable discussions dealing with phases of the situation that may enable us to look at our problem a little differently.

F. W. Perry:—Mr. Kennedy's remarks are rather interesting. I have been a public engineer in New York City for 25 years. The department that I represent has erected bridges, including the longest span of bridge in the world that has floors and takes care of trucks; it has built roadways of the most modern type and it has erected the New York City Municipal Building, of which I was the engineer. It was not all built in a shop, nor were the roads, nor was the bridge. Those parts that must be fabricated from the raw material are built in shops, but they must be fabricated in sections that can be handled by machinery, transported in cars or boats, lifted by derricks and placed and assembled by men. There is nothing visionary about that, but it is a difficult job. The Manhattan Bridge over the East River is today the heaviest bridge standing. It carries a congested load of 61,000 lb. per linear ft. It was designed to the last rivet in the drafting-room of our department, was delivered to New York City in pieces that were hauled up from the barges by derricks and installed in their place. That span is something like 1400 ft. in length. The Municipal Building was erected on a site that included no place to lay down a thing, not even a bag of cement. It is right in front of City Hall, surrounded by streets. A main artery, Chambers Street, was to run through the center of it. That building was erected to a height of 40 stories. Every piece had to come from the Battery, up Broadway, and was lifted directly from the truck by a derrick direct to the place where it will remain until the building comes down.

Ninety per cent of road construction lies in the foundation and the drainage. What is the use of talking about building it in a shop? We are becoming visionary. I am speaking now as a civil engineer, not as an automotive engineer. The wearing surface of a road is renewable and that can be made in a shop; wood blocks, asphalt blocks, brick, granite blocks and concrete slabs can be made there, but not in any size of section that cannot be handled on a one-man basis. Build foundations and you build roads. Drain them after you build them and they will stay there.

France has been metalling roads for hundreds of years. They run in straight lines for hundreds of miles. When the Romans came across the Rhone and went to Paris, they built the roads as straight as the crow flies. They are there yet with the old names on them, although 2 or 3 ft. deep from constant repairs. I have driven over them and, being interested in roads, took occasion to examine them. They are very steep-shouldered; the water is carried away from them and it is not permitted to get on the bed at all under the metal. The Roman roads of early history were so solid that the Roman horses had feet 1 ft. in diameter, there being no resiliency in the road; it is a matter of record. So, do not waste any time in building roads in shops.

One trouble with the road foundation bed is characteristic; it is becoming too thin. Commonly, in New York City, 6 in. of concrete is the customary foundation bed. A subway company may dig and back-fill improperly; a new roadbed will be made, the foundation structure and the smooth wearing surface will be erected on that and soon cracks develop because the structure is weak. The force of the Society's influence ought to be toward proper foundations for wearing surfaces.

A. F. Knobloch:—In regard to the thickness of the road foundation, I do not know whether Mr. Perry has any definite thickness in mind but the Society might well frame a recommendation and submit it to the Federal authorities, in view of the fact that they are now laying their plans for building a system of National highways. Mr. Perry mentioned 6 in. as being the customary thickness of a roadbed or foundation. Perhaps he has a different recommendation. This would be an opportunity to place the force of the Society's influence back of the engineering interests in the Federal Roads Board.

Weight Limitation on Roads

A Member:—I think the Society ought to initiate action in regard to weight limitation on the roads. Wisconsin recently has passed a law limiting truck units to 3½ tons. Florida has done the same thing, and this sort

of legislation is spreading all over the Country. The 7½-ton unit is a very small part of the total number. It seems to me that if we want to engineer, make and sell trucks, we must conform to public sentiment. If we do not conform to it, there will be weight-limitation legislation all over the United States very soon. The thing to do is to work out some sort of a motor-vehicle unit that will comply with the requirements and conform to public sentiment at the same time.

MR. HORINE:—As I interpret the preceding remarks on weight limitation, they propose that we cease producing heavy trucks because the public is opposed to their use on the highways. Motor-truck builders have never forced heavy-capacity trucks on the public, but have built them in response to the demand. If nobody wanted heavy trucks, no company would build them, particularly since it could sell two or more trucks of small capacity to the man who now buys a heavy truck. I would also point out that the enactments of the legislatures of such states as Wisconsin and Florida affect only country roads where the larger motor trucks very seldom run. The demand for heavy trucks is in the cities.

Even if we grant that the legislatures truly represent public sentiment on the matter of truck sizes, and that the general public does prefer to have its goods transported at higher costs by smaller vehicles, I fail to see how we are to work out a unit that will "comply with the requirements," which are for low-cost transportation, and "conform to public sentiment at the same time." If the public demands economical transport and small-capacity vehicles at the same time, the public must be educated to see the fallacy of its demands.

J. F. WINCHESTER:—A point brought out by Mr. Horine is that the 7½-ton truck gradually will disappear. He mentions that there is only a limited number of these trucks in the Country. It is a well known fact that the majority are used in and around the Eastern-coast district of the United States. After watching these and other trucks operate, there is no doubt in my mind that in the last 8 or 10 years they have done a large amount of damage to the highways. Not only has the 7½-ton truck done damage, but this is true also of the smaller units. This is brought about because, in many instances, the trucks themselves have been under-tired for their rated capacity.

The engineer designs a truck for a given load, such as 1 or 2 tons. Then he tells the salesmen the truck can carry 2½ or 3 tons. The salesmen tell their prospective customers that the truck is capable of carrying 4 to 5 tons. The truck builders and large operators of motor vehicles are reaping the results of that kind of engineering and sales work in the restrictive legislation that is being put into force today. It has been stated that there should be a load of 800 lb. per in. of tire width. That is a definite recommendation and, if the Society works along these lines, a great amount of good will be accomplished.

PNEUMATIC TIRES

We are apt to think that good roads exist and that large-size motor-vehicles operate all over the Country. This is not true. In Maryland and in many other States there are practically no large units such as Mr. Horine mentioned. The tax in some of these localities is $500 per truck for trucks of more than 5 tons, which practically precludes their use. Good roads are being built in some of the Southern and Western States. In some of these States the laws do not prohibit the use of trucks up to 7½-ton capacity. We should profit by the mistakes that have been made in more progressive States, for, if the same kind of sales work continues and is permitted in other States where good roads are being built, we will have the same kind of restrictive legislation that is being put into force in New York, New Jersey and other Eastern states.

The argument has been presented that the ultimate solution of motor-truck operation and good roads lies in the pneumatic tire. It has been stated that this is an economical piece of equipment. If compared with a solid tire, this may be true only from a standpoint of road resistance or wear. My experience leads me to believe that the pneumatic tire, particularly in large sizes for truck work, is not an economical unit in the majority of instances and, unless it is developed more in the next 5 years than it has been in the last 5 years, pneumatic tires will gradually disappear from this type of work. Their cost is prohibitive for inter-city hauling or heavy work on trucks of 2½-ton capacity and upward.

The ultimate solution of this problem will lie in the development of a cushion tire, some of which are now being manufactured under the name of semi-pneumatic. The sooner the truck builder starts to counteract the propaganda of the pneumatic-tire manufacturers, the better off he will be, as a great amount of trouble, which is handicapping the sale of trucks because pneumatic tires have been applied, is being experienced all over the Country.

The continued use of the larger units is largely a question of education. Uniform motor-vehicle laws have been proposed. They have failed in many instances because the proposed laws were supported by parties who did not take into consideration the States' or the taxpayers' interests. The result has been that the propaganda put forth by the uniform vehicle-law association is largely being discounted by the various motor-vehicle commissioners, who make recommendations to the State legislatures.

The Society should have more constructive papers of this type. It needs to impress upon the law makers that it is promoting engineering science and accumulating data which will be of value to both sides of the controversy. It may be thought by some that this paper represents the views of one or two large truck companies which produce units of 5 and 7½-ton capacity. There is no question, if careful consideration is given to all the data, many arguments are presented which should be of value in solving the problems of traffic congestion and road up-keep that daily are becoming of greater importance.

A. J. SCAIFE:—I take issue with Mr. Winchester when he says the engineer is passing out exaggerated information to the salesman. I think he will find that the salesman, by constantly coming forward and saying, in effect, "Our competitors are carrying 2000 or 5000 lb. and we must raise the weight limitations," is trying to get the engineer to commit himself.

MR. HORINE:—I think Mr. Winchester misunderstood my remarks about the number of 7½-ton trucks in comparison with those of other capacities. I did not predict their gradual disappearance, for I am confident that as we learn more about the economics of motor transport we will know more about the economy of hauling in large units, as the railroad, the steamship and the rapid-transit companies have gained more information; that the extra cost of building really durable, strong roads will be repaid many times by the lower highway-transport costs effected through the use of the most economical units. Trucks of 7½-ton capacity are not confined to

the Eastern parts of the Country, but are very popular in the Middle West and even on the Pacific Coast.

Mr. Winchester stated that trucks had damaged the roads. That is correct. Trucks do damage the roads. That is what the road is for, to be worn-out. If traffic does not wear them out, we will not build them. In the same way we might argue that tires should not be put on trucks, because they wear out. The conclusion generally drawn is that, because trucks injure roads, the heavier trucks, necessarily, do more damage. I repeat that the damage to the road is not in proportion to the capacity of the vehicle, and that possibly the damage done is due to overloading the truck or other improper operations. One form of improper operation is the practice of wearing tires too thin. It is well known that if a tire wears down to 1 in. of rubber, it might as well be a steel tire.

It is true that if this damage to the roads continues we will have more restrictive legislation. We can expect it and even welcome it, provided the restriction is against the real damager of the road and not merely an unscientific restriction in load capacity.

With regard to the pneumatic tire, I quoted from A. G. Gowans, who made the tests in California; the statements are the results of his tests. Unquestionably, the pneumatic tire has a large field. We do not know its exact limitations, and I shall not attempt to define them.

Mr. Winchester:—The roads are put down to be worn-out, but we must design the trucks and put tires of suitable size on them so there will be ample protection. We are apt to feel that it is a matter of road building, material and the like. The taxpayer feels that it is a combination of conditions. When the taxpayer sees a 5½ or 7½-ton truck that is greatly overloaded, occupies more than its share of the road, runs at an excessive rate of speed and sometimes causes damage through accidents to culverts and traveling roads that never were designed to carry this type of vehicle, a feeling of antagonism toward the vehicle is created.

Drivers and Mechanics

H. M. Rugg:—In reading Mr. Horine's paper I have been particularly interested in connection with the training of personnel. A study of the chart in Fig. 4 of this paper will show that to approximate the desired efficiency to any degree, the matter of trained personnel is involved in nearly all items, in the design or operation of the vehicle and in the construction and maintenance of the highway. In all discussion of service or maintenance or automotive vehicles this subject is generally acknowledged to be of importance, yet it seems to be avoided. The most flagrant disregard is in connection with the operators of the vehicles and the mechanics who keep the vehicles in repair. A trained and skilful truck operator can help to maintain highway as well as vehicle efficiency, and the trained mechanic is certainly essential to high maintenance-efficiency.

One item that might be added to the moving factor, under the heading of Vehicle Efficiency, is breakdown delays. This would cover delays on the road while the truck is in commission. The properly trained operator should be capable of making such temporary repairs as would enable him to reach his destination and possibly return to his own garage or repair-shop. This is similar to the requirements of the railroads. A locomotive engineer usually spends several years in learning to handle the machine and proving that he is reliable before he is permitted to assume the responsibility of operating it. Among the locomotive engineers it is considered almost a disgrace to be "towed-in cold," except under extraordinary conditions. However, in numerous cases we find trucks costing several thousand dollars that are operated by men who know little more than how to handle the steering-wheel and manipulate the pedals. Such a road-delay item also would emphasize the importance of properly trained men for the systematic inspection of vehicles, as well as for repair and overhauling, so that the possibility of such delays can be minimized.

I have been working for the last 3 years on the problems of training personnel. It is amazing to note the small consideration given to this subject by the manufacturers and by engineering bodies. They should be the ones most interested and should even determine the standards for conducting such training.

To keep in repair the 10,000,000 motor vehicles now registered in this Country, there should be at least 350,000 to 400,000 *skilled* mechanics. I have been criticized by manufacturers and dealers as being too conservative in the method of arriving at this figure. Present statistics show that there are approximately 45,000 automotive repair-shops in the United States, which employ about 225,000 mechanics. About 30 per cent are considered competent workmen, and a much smaller percentage than this have a knowledge of the fundamental principles of automobile design and construction. Thus, we have not over 50,000 men properly equipped to do the work for which more than 350,000 are required. It is not unusual for a man who has been washing cars or employed as a helper in one garage to work as an expert mechanic in another. If to this 350,000 men at least an equal number of trained men for properly operating trucks, more especially the larger ones, are added, the size of the educational problems can better be comprehended.

There are no standards for planning an educational program or by which the proficiency of a mechanic can be judged. This has been detrimental to the real school and unfair to its students, and permitted many schools to spring up that have practically no educational value but give the students the idea that they can become *expert* mechanics after a few weeks of attendance. Those in the engineering profession know that "experts" are not made in 6 weeks, 2 months or even 2 years. Continuous application of the knowledge acquired is necessary before a man approximates expertness.

Standards must be established so that this educational work can be properly controlled and conducted. At present the schools are between two fires, so to speak. They know that a relatively long time is required to give the proper training but, on the other hand, they attempt to meet the demands of those applying to receive it in the shortest possible time. Standards, backed by every department of the automotive industry, are the only means of solving our present educational problems. They will also help to lay the foundations of satisfactory service by supplying competent mechanics. If we accept the statement made by Norval Hawkins, of the General Motors Corporation, Detroit, that "Keeping the old cars running is more important than getting the new cars sold," we must admit the necessity of properly trained personnel.

Mr. Horine:—Mr. Rugg refers to the outline given in Fig. 4 in connection with the moving factor. He feels that breakdowns on the road should be made an element of the moving factor. The moving factor comprises only the amount of time spent in moving and in standing while in commission. All standing time, or inactivity while the vehicle is out of commission, is included under the *active* factor.

F. W. DAVIS:—Some of the important matters that are before the truck industry and also before the truck user have been discussed, but I think enough emphasis has not been placed on two items that seriously menace the industry at present, restrictive legislation and the abuse of highways.

Mr. Horine has pointed out that we are in need of a clearer understanding of the economic relation between the vehicle and the highway, but we are face to face today with the fact that there is in process of formation a great amount of legislation that will react very strongly and definitely on the development of the motor truck and its application within the next few years. I was told several months ago that sentiment existed around Boston against the use of heavy trucks because great damage had been done to some of the well known highways by the operation of heavily overloaded trucks at certain seasons of the year when these roads were ill suited to withstand such loads. This sentiment is spreading rapidly and there seems to be a feeling today in the various legislative bodies that not only must the road be protected against this abuse, but that the roads must be classified according to their carrying capacity, with certain seasonal restrictions added.

The State of Connecticut recently has enacted a law that prohibits the carrying of a load in excess of the rated capacity of the vehicle, as registered at the State Capitol. It limits the gross load that can be carried to a specified figure. The first reaction that the motor-truck companies had to this law was a very bitter opposition, a feeling that an unduly severe measure not in accord with the fundamental principles of economic transportation of materials over the highways had been passed. But, in considering the subject further, the manufacturers began to realize that, instead of being pernicious and restricting them in a way that was unfair, this law really offers the salvation to the motor-truck industry that it has been seeking for a long time. It limits the maximum load carried. It means that the violator of the law will be fined.

It is not possible to build roads throughout the Country with adequate foundations and sub-grades to carry enormous loads. Some limit must be put upon the capacities and the roads must be rated according to the means at the disposal of the road-builders. Statistics show that the truck exceeding 5½ to 7-tons in capacity is very much in the minority, possibly less than ½ of 1 per cent of all motor trucks on the highway. Fairness to the road users, who constitute the entire public, would put a sane limit on the vehicles which operate on the highways. The limitation of load per inch width of tire seems to be a very workable figure. Whether this is the ideal is entirely another question. It is determined easily and has many practical advantages.

The matter of axle loads, which are in a sense the overall weight of the vehicle, is another factor that can be determined easily. If the other States will follow the precedent set by Connecticut, a way will be opened for the truck companies to lighten their units and make them more economical in fuel and operating expense. It will also offer the real means whereby the so-called economy of operation can be increased. The example of Connecticut has been followed in almost identical form by New Jersey, and it is reported that the legislatures of New York, Massachusetts and some 12 other States are considering similar legislation.

I do not recognize the capacity of the vehicle as indicating the economy of operation. This is entirely a matter of the loads the vehicle is able to secure and carry throughout its working day. I think no one doubts the essential utility of the motor truck on the highway, but it certainly is time for the industry to exert itself in every way possible to guide legislation along desirable lines and prevent such unfortunate legislation as has been enacted in certain States. If the automotive industry will line up against excessive wheel weights of vehicles that mean the breaking-down of roads and secure the classification of highways and seasonal restrictions, I think public sentiment, instead of being against the truck that on one trip may destroy $300,000 worth of highways, will swing to the other extreme. Then we will not be forced to face the opposition that exists at present.

MR. HORINE:—Concerning the assumption of Mr. Davis that heavy trucks are responsible for the legal limitation of weight, I refer him to the results of the test highway at Pittsburg, Cal., and also to the results of the tests on impact[3] made by A. T. Goldbeck. These references ought to convince him that the impact delivered by a motor truck is not measured by its total weight, that weight is not the most important factor and that impact is not the most important factor. Mr. Davis is correct in stating that large trucks are in the minority. He intimated that it would not be detrimental to legislate them off the road. Proceeding on that basis, we would violate the fundamentals of American justice, particularly if we arraign this heavy vehicle and decide to eliminate it on a presumption that is not borne out by scientific evidence.

Mr. Davis also proposes to classify roads according to their capacity. In general, I believe that would be an excellent thing. No one will gain if the public builds a light road and a type of vehicle destructive to it is allowed to run on it. But if a State classifies its roads, specifying one road for pneumatic-tired trucks and assigning another to solid-tired trucks, and provides that on one road the speed limit shall be 9 m.p.h. and on another 15 m.p.h., the procedure must be not on a basis of the present condition of the roads but of the requirements of traffic. On a back-country road used by farmers, it would not be a hardship to restrict operation to light vehicles with pneumatic tires, because heavy vehicles would not have occasion to use that road; but on a portion of a main-traveled route that, because of improper construction, is incapable of supporting the type of traffic that would naturally flow over it such restriction would be wrong. The restriction should be placed on the highway engineer. The fate of a motor vehicle should not be narrowed down merely to the welfare of the roads. The truck should stand or fall on its economic efficiency. If the truck is advantageous to the community as a whole, it is advantageous for the community to provide a road for that truck; and it is not economic or efficient to restrict traffic on that road to the type of truck for which the road happens to be adapted. It is not economic or efficient to restrict traffic on that road to a type of vehicle that will raise hauling costs above what they should be.

Mr. Davis made a good point in saying that the economy of a truck is not measured by its capacity. The proper capacity of truck for the greatest economy is the size that most nearly meets the requirements of hauling. I hope we will not underestimate the need for heavy vehicles. A large tonnage is being hauled at present on lighter trucks than should be used. This is due to legislative restrictions, to hesitancy on the part of purchasers to invest sufficient money in a vehicle of the size they should have and to a misunderstanding of the fundamentals of operating economy.

[3] See THE JOURNAL, April, 1920, p. 265.

MR. WINCHESTER:—Mr. Davis makes the point that, because of restrictive legislation, it would be just as well to eliminate the designing of trucks of more than 5-ton capacity. It surprises me that a spirit of this kind should be in evidence when scientific data, such as are presented in Mr. Horine's paper, show that the operation of large units, which are necessary in city transportation, tends to cut down the wear-and-tear on the road-bed itself. In many instances the large unit never gets out to the State highway.

MR. HORINE:—Mr. Kennedy suggests that sometimes we get a little too close to our subject. The purpose of this paper is to persuade the automotive industry to overcome its near-sightedness. We would recommend the same process to the highway engineer. We must, as Mr. Kennedy says, get off to a greater distance. The fundamental purpose of the paper is not propaganda; it is a plea for more economic thought.

Mr. Kennedy's suggested line of 1½, 2 to 3 and 5 to 7-ton truck-capacities is really what we have today, because the capacity of the truck is not respected as it should be. The result is that every company is obliged to build its trucks, its springs and its engine with such factors of safety that the trucks can handle severe overloads; at the same time it is necessary to build vehicles having sufficient mechanical efficiency to handle economically loads that are somewhat less than the rated full capacity of the truck.

CHRONICLE AND COMMENT

(*Concluded from page* 304)

tional Automobile Chamber of Commerce has signified its willingness to support this investigation financially and by contributing personnel and equipment; some minor points in the connection remain to be settled. The American Petroleum Institute called a number of oil engineers together at a conference on April 26 to discuss the plans that had been formulated for the joint fuel-research.

After some preliminary tests were run at the Bureau of Standards showing the possibilities of securing reliable results through the comparison of different fuels in cars driven in normal service by average drivers, a supplementary program was drawn up and visits were made to a number of companies building passenger cars in the largest number, with the result that about eight different companies are running road-service tests to determine the effect of fuel volatility on fuel-consumption.

The selection of fuels for test purposes presented some rather complicated questions, as to the number of fuels to be used, the range of volatility to be covered, the limitations to be imposed as to chemical composition and as to refining methods. These questions have involved numerous conferences and visits to refineries which have resulted in the selection of four experimental fuels ranging in volatility from approximately aviation gasoline to a fuel about as bad as commercial gasoline ever gets.

The success of the automotive industry in using the fuels furnished by the petroleum industry has thus far been reasonably satisfactory, but the future holds problems more acute than those of the past. The petroleum refiners have been devising means for making more and more gasoline without undue increase in the end-point, and the automotive engineers have in turn been endeavoring to design engines that will utilize better the heavier fuels that the refiners have predicted; a process that might have been endless had its seriousness not been realized a little over a year ago.

At that time the joint obligation of the two industries was recognized in the undertaking of a joint fuel-research program that has been planned to deal, not with remote possibilities of a radical change in engine design or in fuels, but with a single definite problem affecting engines and fuels as they exist today. This program calls for an answer to the question, What Are the Relations between Fuel Volatility, Fuel-Consumption of the Average Vehicle, and Fuel Produced per Barrel of Average Crude?

A barrel of crude oil will produce more or less gasoline, depending upon its volatility. If the volatility be correctly chosen, the total ton-miles of transportation per barrel of crude will be a maximum. If unnecessarily volatile, the amount of fuel will be small and the mileage less. If too poor, while the quantity of fuel will be larger, the miles per gallon will be less and the total ton-miles will be again less than the maximum.

A systematic research program to accomplish the desired result has now been started, under the supervision of the Research Department of the Society, which department will compile the results of the tests as well.

The United States Bureau of Mines is in charge of the specifications of the fuels to be used and will make tests as to their quality, as well as control tests on fuel samples submitted by the various companies running tests.

The United States Bureau of Standards has designed and built for use in the road-testing of passenger cars representing large production, a most complete layout of indicating and recording instruments by which accurate records of fuel-consumption and all elements of car performance can be made under all conditions of road service. Thus the effect of the experimental fuels on both car mileage and car performance will be accurately known. An extensive series of road tests is being run by the Bureau of Standards, making use of fleets of Government-owned vehicles. This program will require the use of about 80,000 gallons of fuel in several hundred vehicles. Various cities have been selected in which to run the tests because of their divers road conditions.

When the different tests contemplated shall have been completed, the Research Departments of the American Petroleum Institute and of the Society of Automotive Engineers should be in a position to supply the industries they represent with information that will make possible better economic use of the petroleum resources, and longer postponement of the time when costs of fuel will retard the development of automotive transportation.

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

PHYSICAL PROPERTIES OF MOTOR FUELS. By W. R. Ormandy and E. C. Craven. Paper read before the Institution of Automobile Engineers, 28 Victoria Street, Westminster, S. W., London, England. 27 pages; 8 illustrations.

In considering the suitability of various fuels for use in commercial motor-car practice, the most important item is *not* the cost per gallon, but the *cost per unit result.* To insure economical operation a fuel must possess certain physical and chemical characteristics, which are discussed in detail in this article. Many of the data are taken from the recent publications of Ricardo and his associates.

A satisfactory fuel must have a high heat of combustion which is capable of efficient utilization. Certain substances, such as acetylene, possess high heats of combustion but cannot be used easily in the engine. It is also necessary that the fuel have a fairly low freezing-point. For this reason benzol must be mixed with some other fuel, usually a paraffin, for use in cold weather. This requires mutual solubility of the fuels used, and it has been found that certain mixtures of fuels, especially those containing alcohol, begin to separate at moderately low temperatures. Data are given for the mutual solubility of various mixtures of benzol and alcohol with other fuels.

A low initial boiling-point can be taken as an indication of the flash-point, or relative ease of starting of the fuel. A comparatively low 50 per cent point is a good indication of satisfactory behavior in the engine. High final-distillation temperatures indicate the presence of heavy fractions which possess the tendency to get by the rings into the crankcase and dilute the oil. British and Continental fuels are markedly superior to American fuels in this respect.

The latent heat of evaporation is an important factor in the carburetion of the fuel. Where a large amount of heat must be supplied it is necessary to make use of some auxiliary heating device such as the hot-spot. If a fuel with a high heat of vaporization is admitted to the cylinder in the form of spray, then the cooling of the charge and cylinder walls by evaporation makes possible a high volumetric efficiency.

Probably the most important factor in determining the starting qualities of a fuel is the amount of readily volatile material it contains. The authors have shown recently that the flash-point is capable of giving a very good idea of the amount of these volatile hydrocarbons present. The flash-points of engine gasolines are of the order of —25 deg. cent. (—13 deg. fahr.) to —30 deg. cent. (—22 deg. fahr.), of fuel benzol about —11 deg. cent. (+12 deg. fahr.), and of 95 per cent alcohol 16 deg. cent. (61 deg. fahr.). The flash-points of various hydrocarbons occur, within very small limits, at the same vapor-pressure. The lower limit of flame propagation for all hydrocarbon-air mixtures is at approximately 1½ per cent by volume of the combustible vapor, while the maximum limit is at about 4½ per cent by volume. Both the lower and higher flash-points appear to bear a constant ratio to the initial boiling-point of the fuel when all are expressed in degrees of absolute temperature.

There are several other important requirements for motor fuels; they must not exert corrosive action on the metals with which they come in contact; they must possess a fairly uniform viscosity, this is especially desirable in connection with use in jet carbureters, and they must not show too great a tendency to detonate. The detonation tendency of a fuel is indicated by its "toluene value," a notation developed by Ricardo. The authors attempt to trace a fairly definite relationship between the temperatures of spontaneous ignition and the "toluene values" of the fuel.

Referring to the development of high-efficiency high-compression engines the illuminating remark is made: "It will gradually become realized by the purchasing public that the super-efficient engine is only super-efficient when supplied with certain fuels, and that with unsuitable fuels it can become a 'super-nuisance.'" D. P. B. 4th.

THE AIRPLANE ENGINE. By Lionel S. Marks. Published by the McGraw-Hill Book Co., New York City. 454 pages; 341 illustrations.

This volume should be an important and useful addition to the literature on this subject. The author has collected and compiled in very convenient and acceptable form many of the reliable data regarding the principles of design and practical operation of all classes of typical aircraft engines in present use and has treated these data with a full regard for the underlying principles of mechanics and thermodynamics, making his interpretations of particular value.

Among other things, the volume contains well-analyzed results of tests and observations gathered from a great variety of sources, some of which are difficult of access. Naturally some of these results are impossible to verify, but the author has for the most part either omitted or qualified such statements as did not appear to be in reasonable accord with known facts or accepted theories. The author wisely makes no attempt at prediction or invention, but confines himself to what may be classed as present knowledge, presenting this in such a form as to be useful to all interested in aircraft powerplants.

AN INVESTIGATION OF THE FATIGUE OF METALS. By H. F. Moore and J. B. Kommers. University of Illinois Engineering Experiment Station. Bulletin No. 124. 185 pages; 46 illustrations.

This bulletin is in reality a progress report on a very important investigation begun several years ago under the sponsorship of the National Research Council, and with the cooperation and support of various commercial interests. Failures of steels under repeated stress have presented a difficult problem that became acute during the war. No entirely satisfactory methods of testing for this property were available. The results of tests of a large variety of steels by all the accepted and by some new methods described and carefully analyzed in this bulletin throw much new light on the subject. Some very constructive suggestions are made for the continuation of this line of research.

ABRASIVE WHEEL SAFETY CODE

A CODE containing the rules and specifications considered necessary to insure safety in the use of abrasive wheels operating at speeds in excess of 2000 surface ft. per min., which was prepared by a sectional committee organized under the joint sponsorship of the Grinding Wheel Manufacturers Association of the United States and Canada and the International Association of Industrial Accident Boards and Commissions, has been approved as a tentative American standard by the American Engineering Standards Committee. Representatives of the various engineering societies and trade associations interested in the use of grinding wheels were among the members of the committee, the Society's representative being A. J. Gifford. The sections into which the code is divided deal with types of protection devices, storage and inspection of wheels, general machine requirements, protection hoods, work rests, protection of wheels, flanges, methods of mounting, operating rules and general data. Numerous illustrations supplement the text.

ACTIVITIES OF THE SECTIONS

Secretaries of the Sections

BUFFALO SECTION—E. T. Mathewson, Acting Secretary, 321 Fidelity Building, Buffalo
CLEVELAND SECTION—E. W. Weaver, 5103 Euclid Avenue, Cleveland
DAYTON SECTION—R. B. May, Dayton Engineering Laboratories Co., Dayton, Ohio
DETROIT SECTION—B. Brede, Assistant Secretary, 1361 Book Building, Detroit
INDIANA SECTION—B. F. Kelly, Weidely Motors Co., Indianapolis
METROPOLITAN SECTION—F. E. McKone, 347 Madison Avenue, New York City
MID-WEST SECTION—T. Milton, 140 South Dearborn Street, Chicago
MINNEAPOLIS SECTION—C. T. Stevens, Reinhard Brothers Co., Minneapolis
NEW ENGLAND SECTION—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston
PENNSYLVANIA SECTION—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
WASHINGTON SECTION—B. R. Newcomb, 211 Victor Building, City of Washington

DURING the past month all of the Sections have received the annual Society appropriation of $1 for each member of the Section in good standing as of March 1. This appropriation is additional to the $500 that is sent to each Section at the beginning of the Section year, Oct. 1, by the Treasurer of the Society. The following list presents the membership totals of the 11 Sections:

Buffalo	27
Cleveland	93
Dayton	69
Detroit	303
Indiana	39
Metropolitan	197
Mid-West	82
Minneapolis	17
New England	59
Pennsylvania	63
Washington	25
Total	974

SECTIONS AND THE SUMMER MEETING

Several of the Sections have completed arrangements with the local railroad authorities for special Pullmans to transport their members to the Summer Meeting at White Sulphur Springs. In most instances these special cars will depart during the afternoon of June 19 and arrive at White Sulphur Springs on the morning of June 20 without the members having the inconvenience of any change or stopover. The Section Secretaries are being advised weekly of the members in their territory making reservations with the Society for hotel accommodations at the Summer Meeting, this service enabling the Secretaries to call the attention of these members to the advantages of traveling on the special trains. Your Section Secretary is provided with complete information and should be consulted before you purchase your transportation. A table showing the reduced fares and train schedules will be found on page 346 of this issue of THE JOURNAL. Members of every Section of the Society will profit by the reduced-fare arrangement at the 1922 meeting, the saving amounting to 25 per cent of the round-trip fare in all cases.

One of the features of the 1922 Summer Meeting will be the inter-Sectional athletic contests. The Society baseball championship series will be played to decide which Section will capture the cup now in the possession of the Metropolitan Section. There will be tug-of-war events between teams representing the various Sections. A relay race will also be contested. Word reaches us that the members of the Metropolitan Section baseball team have been perfecting their nine during the spring season, for they have no intention of having the trophy wrested from them.

It is expected that the Section stunts of previous years will be outdone at White Sulphur Springs. As announced last month, L. L. Williams is busy adding another ring to Cleveland's celebrated Burnum & Baleum exposition of the big tent which was showered with approval at West Baden. A. K. Brumbaugh is endeavoring to rejuvenate the dragon of Ottawa Beach fame. Mark Smith is studying another of the classic tongues and may burst forth at any moment in a new impersonation. Naturally the rivalry is heated and much good-natured tomfoolery will result.

SOCIETY NOMINATING COMMITTEE MEMBERS AND NEW SECTION OFFICERS

Section	*Member*	*Alternate*
Buffalo	O. J. Rohde	
Dayton	V. G. Apple	L. S. Keilholtz
Detroit	Howard A. Coffin	T. J. Litle, Jr.
Mid-West	B. S. Pfeiffer	Taliaferro Milton
Metropolitan	Cornelius T. Myers	Finley R. Porter
Pennsylvania	T. F. Cullen	F. M. Germane
Washington	W. S. James	

Each of the Sections elected its representative on the Society Nominating Committee during the past month. This Committee is charged with the selection of a ticket of general

Schedule of Sections Meetings

MAY

3—MINNEAPOLIS SECTION—Business Meeting
8—INDIANA SECTION
12—MID-WEST SECTION—Fundamental Losses in Automotive Apparatus
12—NEW ENGLAND SECTION — Manufacture of Tires—W. W. Duncan. Also Special Entertainment
18—CLEVELAND SECTION—Coordination of Automotive Research
19—DETROIT SECTION—Cylinder-Wall Surfacing Methods
25—PENNSYLVANIA SECTION—Either Outing at Torresdale or Body Meeting
BUFFALO SECTION—No Meeting Scheduled
DAYTON SECTION—No Meeting Scheduled

Society officers to be voted on for 1923, and will perform this important duty during the Summer Meeting at White Sulphur Springs. The annual Nominating Committee consists of one member of the Society elected by each Section prior to the Summer Meeting and three members-at-large who are elected at the business session of the Summer Meeting. The names of the Nominating Committee members that have been received at this date appear on the preceding page.

Each of the Sections of the Society elected its officers for the 1922-1923 year during April, the names of those who are to take office next fall having been announced at the May meetings. The complete list of these officers will be published in the June JOURNAL.

RECENT AND FUTURE MEETINGS

Detroit Section—The Detroit Section is indebted to K. L. Hermann for the arrangement of an extremely interesting and instructive production-engineering meeting on the evening of March 24. Over 225 members and guests were in attendance and heard four papers presented on the general topic of Gearing. The technical meeting was preceded by a buffet supper.

S. O. Bjornberg described several ingenious inspection and measuring fixtures in his paper, How to Use Hobs. He illustrated his talk with lantern slides and showed how the accuracy of gear hobs can be checked to assure the exact cutting of gears with teeth of the desired profile. R. S. Drummond presented a paper on the advantages of gear grinding. He called attention to the inaccuracies in tooth profile caused by the hardening process, thus demonstrating the importance of grinding the tooth face after hardening when silent running of the gears is essential. He believes that wear is greatly accelerated in the case of gear teeth that are not ground accurately to theoretical form. A paper by John Edgar treated certain features of the gear-hobbing machine that require careful adjustment to attain accurate results. He stressed the importance of using very precise hobs.

Following the presentation of the papers, a device was demonstrated that projected tooth-profiles, greatly enlarged, upon a screen and permitted comparison of the actual form with the theoretical outline.

The papers elicited very active discussion. The success of this production session indicates the advisability of the scheduling of similar meetings by the other Sections of the Society.

The April meeting of the Detroit Section was devoted to the very troublesome problem of lubricating-oil dilution in engine crankcases. William F. Parish presented the paper of the evening. He described a system that has been designed to carry the lubricant from the crankcase through an exhaust-heated distillation device to remove the diluent from the oil. The treated oil is returned to the crankcase through a cooler and the diluent collected and burned in the cylinder. Mr. Parish gave several demonstrations which added greatly to the interest in his paper.

At the Detroit Section Meeting to be held on May 19 papers will be presented on methods of producing cylinder-wall surfaces. The production problem involved is to be studied particularly from the standpoint of preventing oil-pumping and crankcase lubricating-oil dilution.

Minneapolis Section—The Minneapolis Section departed from its general practice of treating farm power and tractor topics, at its meeting held on April 5. Victor Gauvreau, instructor of mechanical engineering at the University of Minnesota, presented a paper on the Influence of Racing on Automotive Design. Mr. Gauvreau was engaged in the design of racing cars for several years. He enumerated some of the constructional improvements in car and engine design that are the result of racing experience.

The officers of the Section are making plans for a Summer Outing to be participated in by members resident in the Section territory.

Metropolitan-New England Sections—On April 21 the Metropolitan and New England Sections visited New Haven, Conn., where a joint meeting was held at the Mason Automobile Laboratory of the Sheffield Scientific School of Yale University. After a very enjoyable luncheon at the Yale Dining Club, the members inspected the laboratory apparatus, evincing particular interest in the dynamometer for measuring overall car-efficiency. Prof. E. H. Lockwood presented a very comprehensive and instructive paper on Motor-Vehicle Testing, in which he discussed many of the elements of power loss between the engine and the road. His test results and treatment of tire losses were particularly valuable, inasmuch as the effects of speed, type of tread, condition of tire with regard to wear, degree of inflation and many other variables were clearly shown.

A very novel feature of the meeting was the transportation to New Haven of 65 Metropolitan Section members by gasoline-engined rail-cars. These members traveled the entire distance via the gasoline route, the first stage of the trip being made by motorbus. The rail trip was arranged through courtesy of officials of the New York, New Haven & Hartford Railroad.

The Metropolitan Section's Annual Carnival was held on the evening of April 29. All of the plans and arrangements were made by a committee of members' wives and they set a very high standard for similar occasions in the future. Supper, dancing and entertainment drove away automotive business cares.

The New England Section has secured from W. W. Duncan a paper on the Manufacture of Tires, which will be read at its meeting scheduled for May 12.

Washington Section—E. C. Crittenden presented a paper on the Automobile Head-Lamp Problem before the Washington Section on the evening of April 7. Mr. Crittenden has been directly interested in the studies made to develop a means of measuring head-lamp illumination glare. He summarized the requirements, both legal and technical, that resulted in the most recent revision of the Illuminating Engineering Society's specifications. There was considerable discussion of the subject, it being the consensus of opinion that better regulation of head-lamp illumination is demanded. The Lighting Division of the Standards Committee of the Society will consider head-lamp intensity standards at its May meeting.

Indiana Section—The Indiana Section did not meet during April but an unusually attractive program was arranged by it for the evening of May 8. The Section will have many of the officers of the Society as its guests on this occasion, as the Council will meet in Indianapolis on the same day.

Cleveland Section—On April 21 a very interesting meeting and an inspection trip were conducted jointly by the Cleveland Section of the Society and that of the Illuminating Engineering Society. The Sections met during the afternoon at the miniature lamp factory of the National Lamp Works, where the members had an opportunity to observe the methods followed in the production of automobile-lamp bulbs. A new process of bulb manufacture was inspected later at the Pitney Glass Division of the same company. Dinner was provided at the Nela Park dining-rooms after the inspection trip, the company acting as host. Soon after dinner the Section adjourned to the lecture-room of the Nela Laboratory, where a paper on Motor Vehicle Lighting was read by H. H. Madgsick.

The Cleveland Section has secured Dr. H. C. Dickinson, manager of the Society's Research Department, to talk to it on May 18 on the Advantages of Coordinating Automotive Research.

Buffalo Section—The Buffalo Section devoted its meeting on April 18 to the topic of ball bearings. Dr. Tobias Dantzig gave a paper on the Design and Construction of Ball Bearings and Their Automotive Applications. Doctor Dantzig's paper, which was received most favorably, was followed by discussion of ball-bearing mountings and standards.

No meeting has been scheduled by the Buffalo Section to be held during May.

Pennsylvania Section—The Pennsylvania Section met on the evening of April 27. Cornelius T. Myers read a paper

(*Concluded on page* 439)

Current Standardization Work

THE Standards Committee Division meetings held during April were most successful. Several recommendations were approved for submission to the Standards Committee at the Summer Meeting at White Sulphur Springs on June 20. These recommendations are mentioned in the accompanying summary of the current standardization work and will be printed in full in the June issue of THE JOURNAL, which will contain the Reports of the Divisions to the Standards Committee. The members should therefore plan to bring the June issue of THE JOURNAL to the Summer Meeting to follow the work in the Standards Committee Sessions. Members especially interested in any of the current Division recommendations can obtain advance copies of them from the Society upon application.

The meetings held during April are listed in Table 1.

TABLE 1—APRIL MEETINGS HELD

Agricultural Power Equipment Division	April 19
Ball and Roller Bearings Division	April 28
Engine Division	April 17
Electrical Equipment Division	April 14
Electric Vehicle Division	April 5
Iron and Steel Division	April 11
Lubricants Division	April 18
Motorboat Division	April 10
Nomenclature Division	April 3
Parts and Fittings Division	April 12
Passenger-Car Hubs Subdivision	April 7
Sectional Committee on Ball Bearings	April 27
Stationary Engine Division	April 19
Thrust Ball Bearing Subdivision	April 18
Transmission Division	April 13

MAY DIVISION MEETINGS

The schedule of May meetings, published in the April issue of THE JOURNAL, has been revised slightly. The dates of the May series of meetings are therefore reprinted in Table 2. It should be appreciated that these dates are not final, but are intended to help the members of the Divisions arrange their plans far enough ahead to attend meetings. Definite meeting notices have been or will be sent to all Division members at least 2 weeks in advance of each meeting scheduled.

AUTOMOBILE WIRING

A Subdivision was appointed at the Electrical Equipment Division meeting on April 14 to formulate standards for automobile wiring based on the paper presented by W. S. Haggott at the Buffalo Section Meeting on April 21. The personnel of the Subdivision is

W. S. Haggott, chairman,	Packard Electric Co.
H. B. Burley,	Boston Insulated Wire & Cable Co.
B. M. Leece	Leece-Neville Co.
M. L. Hillmer	Remy Electric Co.
Ernest Wooler	Cleveland Automobile Co.

Consideration was given also to the standardization of cable clips and rubber bushings. As it was felt that these subjects are intimately related to that of automobile wiring, they were assigned to the same Subdivision. It was brought out that cable terminals in accordance with the present S. A. E. Standard, pages B21 and B22 of the S. A. E. HANDBOOK, are used very little and that it would be better to select terminal designs which are common practice and adopt them as standard in place of the present S. A. E. Standard.

BALL STUDS

At the meeting of the Parts and Fittings Division on April 12 the following Subdivision was appointed to revise the report on ball-studs, which was referred back for further consideration to the Division at the June, 1921, meeting of the Standards Committee:

E. R. Douglas, chairman,	Cincinnati Ball Crank Co.
H. B. Garman	Detroit Steel Products Co.
W. J. Outcalt	General Motors Co.

BRAKE-LINING

A meeting of the Brake-Lining Subdivision was held in New York City on March 28. The results obtained by several brake-lining manufacturers who had been running tests on a brake-lining testing-machine developed at the Bureau of Standards were discussed and indicated that it is very doubtful whether uniformity of results can be obtained by the use of the machine, especially when the tests are run by different operators.

The speed of the drum used by the various companies making these tests ranged from 540 to 650 r.p.m. The time required to wear the brake-linings to one-half their original thickness varied from 5 to 43 hr. The coefficients of friction determined varied from 0.420 to 0.581. The differences in results obtained, it was decided, could not be attributed

TABLE 2—TENTATIVE SCHEDULE OF DIVISION MEETINGS IN MAY

Division	Cleveland	Detroit	New York City
Aeronautic			May 15
Wire and Fittings Subdivision			May 10
Axle and Wheels	May 2[a]		
Electric Vehicle		May 10	
Lighting	May 3		
Motorboat Lighting Subdivision			May 2
Motorboat			May 23
Non-Ferrous Metals	May 1		
Parts and Fittings		May 9	
Passenger Car	May 2[a]		
Passenger-Car Body		May 8	
Screw-Threads	May 1		
Springs		May 5	
Storage Battery			May 5

[a] Joint meeting.

solely to the differences in speed, and it was brought out that the nature of the surface of the drum itself has a material effect on the life of the lining. It was concluded that it would be necessary to have the drums mounted and ground concentrically with the shaft and polished before starting the tests, but the general opinion was that the machine is too sensitive to variations of adjustment to give satisfactory uniformity of results.

A proposed modified design of testing machine was discussed and a Committee appointed to communicate with engineers of the Riehlé Bros. Testing Machine Co. to obtain their opinion as to its design.

The present S. A. E. Standard for Brake-Lining was discussed, it being considered advisable to incorporate in a general specification covering both woven and folded types of brake-lining the brake-lining dimensions specified in the present S. A. E. Standard. It was recommended that the tolerances for the width be changed from plus to minus 1/16 in. for all sizes to plus or minus 1/32 in. up to and including the 2½-in. width and plus or minus 1/16 in. for sizes over 2½-in. width. It was also recommended that the width and thickness should be measured with "go" and "no go" gages with jaws 1 in. wide.

BREAKER-CONTACTS

At the Electrical Equipment Division meeting in April it was decided to recommend for adoption as S. A. E. Recommended Practice ¼ in. for the width across the flats of the hexagon head of breaker-contacts and of the check-nut used, and No. 10-40 or No. 8-40 thread. The adoption of this recommended practice will make it necessary to use but one size of wrench for breaker-contacts and facilitate servicing in emergencies. The diameter across the contact-points was not considered for standardization as this was thought to be a matter of individual design.

CLUTCH-BEARING OILING MECHANISMS

At the meeting of the Transmission Division on April 13 it was decided that the standardization of clutch-bearing oiling mechanisms is impracticable because of the great variety of individual designs that would be affected and the difficulties encountered in trying to provide an adequate standard method. This subject was therefore discontinued.

CLUTCH FACINGS

S. O. White and L. C. Fuller have been appointed members of the Subdivision on Clutch Facings to co-operate with A. C. Bryan, chairman of the Transmission Division, who is working on the further standardization of clutch facings with special reference to rivets and parallelism of facings.

In discussing different methods of testing the parallelism of clutch facings at the April Transmission Division meeting, A. W. Copland suggested that the members of the Division work up several designs of inspecting mechanisms and distribute information as to them to the Division members. Mr. Bryan felt that it might be well to establish standard methods of inspection in order to obtain uniform results from all clutch-facing manufacturers.

CLUTCH STANDARDIZATION

The April meeting of the Transmission Division was called primarily to consider the standardization of clutches, the Society having received several suggestions in connection with this subject. C. G. Wood presented information covering trouble that the clutch and car manufacturers experience owing to the lack of standardization of clutch mountings. He referred to the tendency for the single-plate and multiple-disc clutch to replace the cone clutch and urged the Division to formulate standards for interchangeable mounting dimensions of single-plate and multiple-disc clutches. He submitted a sketch showing the possibility of such standardization, this indicating maximum dimensions to cover the most extreme cases.

General discussion indicated that the standardization of single-plate clutches is feasible, but that difficulty will be encountered in connection with the multiple-disc type. Mr. Copland suggested standardizing the connections between the driving gear and the clutch, pointing out that this is one of the important points in clutch mounting. He emphasized the importance of standardization as one of the principal economic factors in parts manufacturers' business.

Mr. Bryan brought up the matter of the advisability of standardizing the tolerances for spline fits, particularly in connection with the widths of splines on the driving-shafts and in stem gears. It was suggested that it would be well to develop standard fixtures and methods of inspecting splines to eliminate the possibility of controversy between manufacturers and consumers; also that there might be two classes of standards, one for very accurate high-grade work and the other class for less expensive work.

As it was the consensus of opinion that the subject of clutch standardization should be actively followed up, Chairman Bryan appointed the following Subdivision to investigate both single-plate and multiple-disc types of clutches and to prepare a report on their standardization:

D. E. Gamble, chairman,	Borg & Beck Co.
C. E. Swenson	Mechanics Machine Co.
C. G. Wood	Hoosier Clutch Co.
L. C. Fuller	Fuller & Sons Mfg. Co.
R. C. Merchant	Covert Gear Co.
H. W. Sweet	Brown-Lipe Co.

Mr. Bryan indicated that the Subdivision members should proceed in two groups for the present, the first three members of the Subdivision working on single-plate clutches and the last three on multiple-disc clutches. As soon as these two groups shall have obtained the necessary data and formulated a general idea of what is necessary with regard to each particular type of clutch, all the Subdivision members will confer in the preparation of the final report to the Transmission Division.

COTTER-PINS

A Subdivision was appointed at the April meeting of the Parts and Fittings Division to review the present S. A. E. Standard for Cotter-Pins, page C7 of the S. A. E. HANDBOOK. The Subdivision appointed was

W. C. Keys, chairman,	Gabriel Mfg. Co.
W. J. Outcalt	General Motors Co.

CRANKCASE DRAIN-PLUGS

At the April meeting of the Engine Division it was recommended, for consideration by the Standards Committee, that crankcase oil-drain holes shall have a minimum opening of ¾ in., be located at the lowest point in the oil-pan and be operable from under the engine hood. Owing to the large number of different engine designs and satisfactory types of oil-drain, the Division felt that further standardization would limit the engineering development of such mechanisms.

ELECTRIC VEHICLE DIVISION MEETING

Work was started in connection with the different subjects before the Electric Vehicle Division at the first meeting of the year held on April 5.

It was thought desirable to establish definite dimensions for battery trays for electric trucks so that batteries and battery assemblies can be readily interchanged. E. L. Clark and Bruce Ford were appointed to act as a Subdivision to obtain information on present practice and formulate a report for consideration at the next meeting.

A recommendation was adopted eliminating the 50-amp. charging-plug and receptacle from the present S.A.E. Standard on page B38 of the S. A. E. HANDBOOK. This action was taken because trouble is experienced in charging-stations when using different sizes of plug and also on account of trouble caused by bad contact and resultant overheating when using the smaller plugs.

It was felt that terminal locations and polarities, as well as the types of terminal at the corners of storage-battery compartments, should be standardized. H. M. Pierce was ap-

pointed a Subdivision of one to obtain information on present practice and to prepare a report for consideration at the next meeting of the Division.

The present rather varied practice among electric-vehicle builders as to lamp voltages and sizes was discussed in connection with different State head-lamp laws. After thorough discussion, it was recommended that all incandescent lamps for electric vehicles shall be of a standard double-contact bayonet type and that for nominal 40 to 44-volt circuits incandescent lamps for tail-lamps, side-lamps and dome-lamps shall be 8-watt of the G-10 size, and those for head-lamps 15-watt of the S-11 size; and that for a nominal 80 to 84-volt batteries all lamps shall be 15-watt of the S-11 size. The poor quality of bases and sockets manufactured at present was emphasized. It was understood that there had been considerable discussion of this subject and that many improvements are being developed, which give assurance that satisfactory lamp fixtures can be obtained generally in about six months.

Emergency Rim-Clamps

The Axle and Wheels Division has voted to discontinue further consideration of emergency rim-clamps and the Subdivision, consisting of C. C. Carlton, chairman, G. L. Lavery, J. G. Swain and H. W. Kranz, has been discharged.

In 1920 the problem of formulating a means for interchanging different-size rims on motor trucks was assigned to a Subdivision of the Truck Division. A recommendation was submitted at the January, 1921, Standards Committee meeting, but referred back to the Division for further consideration. This recommendation was printed in the February, 1921, issue of The Journal. The subject was then referred to the Axle and Wheels Division, the Subdivision now discharged having been appointed in May, 1921. The Subdivision held a meeting in West Baden in 1921 in which the standardization of emergency rim-clamps was very thoroughly discussed and the decision reached that everything that had been suggested up to that time was impracticable.

Felt Specifications

Specifications for felt were approved at the April meeting of the Parts and Fittings Division for submission to the Standards Committee in June. The complete specifications cover the general classifications; character, such as "soft," "firm" or "hard"; width; weight per running yard per thickness; percentage of wool; color; tolerances and application. The principal specifications are given in Table 3. The complete specifications will be published in the June issue of The Journal.

The specifications are to be circularized among felt, axle, wheel, body and automobile manufacturers and the specifications reconsidered in the light of any comment received at the Division meeting on May 15.

Flexible Discs

The Parts and Fittings Division has tabled the subject of flexible discs, as it is of the opinion that interchanging discs and coupling spiders of different makes is not desirable and that the many methods of fastening the couplings to the discs, affecting such standardization, would introduce patent difficulties. It was also thought that it would be difficult to place responsibility in cases of dispute where parts of different makes are used, due to the different characteristics of the material.

Flywheel Housings

At the Engine Division meeting held on April 17 it was recommended that the clearance space for crankshaft flywheel bolts specified in the present S.A.E. Standards for Flywheel Housings, page A1 of the S.A.E. Handbook, should be revised. The present standard specifies that the minimum diameter of the clearance space for crankshaft flywheel bolt nuts shall be 6⅛ in. and the minimum depth ⅝ in. To allow sufficient clearance when U. S. Standard nuts or S.A.E. Standard nuts with cotter-pins are used, the Division recommends that the minimum diameter of the clearance space shall be 6½ in. and the minimum depth ¾ in.

Front-Axle Hubs

At the meeting of the Passenger-Car Front-Axle Hubs Subdivision held on April 7 further progress was made on motor-truck and passenger-car front-axle hub standardization.

A tentative series of dimensions for passenger-car front-axle hubs was laid out based upon a chart showing present practice compiled by Cornelius T. Myers. Definite dimensions for the bearing layout are still to be determined, as well as for the flange and bolt-circle diameters and other detail dimensions. It is hoped that final Subdivision action can be taken in time for consideration at the Axle and Wheels Division meeting in May, but, as it is wished to have the final Division recommendation receive wide consideration, it is not planned to submit it for final action at the Standards Committee meeting next month.

The Subdivision recommended that a supplementary table, containing data on tire sizes and capacities, weights on front axles and similar data upon which the present S.A.E. Recommended Practice for Motor-Truck Front-Axle Hubs, page F1b of the S. A. E. Handbook, was based, be published as an appendix to the present recommended practice. This

TABLE 3—FELT SPECIFICATIONS

Specification No.	Class	Character	Wool Percentage	Color
50-A	Pad Felt	Soft, Lofty	50 to 55	Grey and White
60-A	Pad Felt	Soft, Lofty	60 to 65	Grey and White
70-A	Pad Felt	Soft, Lofty	70 to 75	Grey and White
80-A	Pad Felt	Soft, Lofty	80 to 85	Grey and White
70-B	Pad Felt	Firm, Heavy	70 to 75	Grey, Black and White
80-B	Pad Felt	Firm, Heavy	80 to 85	Grey, Black and White
90-B	Pad Felt	Firm, Heavy	90 to 95	Grey, Black and White
95-B	Pad Felt	Firm, Heavy	95 to 100	Grey, Black and White
100-B	Pad Felt	Firm, Heavy	100	Grey, Black and White
80-C	Backcheck	Very Firm	80 to 85	Grey, Brown, Pink, Green, White
90-C	Backcheck	Very Firm	90 to 95	Grey, Brown, Pink, Green, White
95-C	Backcheck	Very Firm	95 to 100	Grey, Brown, Pink, Green, White
100-C	Backcheck	Very Firm	100	Grey, Brown, Pink, Green, White
95-D	Sheet Felt	Hard	100	Grey, White
100-D	Sheet Felt	Hard	100	Grey, White
100-E	Upper Felt	Shoe (Smooth Firm)	100	Grey, Brown, Black, Pink, Green, White
100-F	Upholstery	Smooth, Firm	100	Grey, Brown, Black, Pink, Green, White
80-G	Channel	Sole (Very Firm)	80 to 85	Grey, Black
90-G	Channel	Sole (Very Firm)	90 to 95	Grey, Black
95-G	Channel	Sole (Very Firm)	95 to 100	Grey, Black
100-G	Channel	Sole (Very Firm)	100	Grey, Black

action was taken because it is felt that the recommended practice as published at present is incomplete in that it does not explain how it was arrived at or provide any guide for the designer as to which hub and spindle size should be selected for a given application. It is also thought advisable to specify the diameter, pitch and length of thread for the threaded-end of each spindle, to make the recommended practice of real value to the manufacturers and provide a suitable means for securing uniform practice for machining axles and locking the bearings on the spindle.

The desirability of establishing a standard diameter and pitch of hub-cap thread was discussed. It was thought that, although different car-makers usually want individual hub-cap designs, a standard could be formulated that would be of benefit to the hub and wheel manufacturers without destroying the possibilities of individuality. A. S. Van Halteren was appointed a Subdivision of one to investigate the possibility of such standardization. It was also considered desirable to specify the dimensions for square-neck hub-bolts for motor-truck hubs. It was decided to consider at the next meeting adopting the standard formulated by the Wood Wheel Manufacturers Association.

Gasoline-Tank Fillers

The limiting of gasoline-tank filler-pipe openings to a minimum size was discussed at the April meeting of the Parts and Fittings Division. It was decided that passenger-car, truck and gasoline-pump manufacturers should be circularized as to their present practice in regard to the diameter of filler-pipe openings and nozzle sizes and as to their criticism of a minimum opening-diameter of 2 in.

Generator and Starting-Motor Mountings

The present standards for generator and starting-motor mountings were carefully reviewed at the meeting of the Electrical Equipment meeting on April 14, a report being submitted by the Subdivision appointed to review the standards.

The Subdivision on Generator and Starting-Motor Mountings reported that the standardization of generator strap-mountings is not feasible in view of the widely varying diameters in which generators are built and because there is no real demand for such a standard. It was therefore decided to table this subject indefinitely.

The Subdivision reported that the generator lengths between the shoulders of the shaft cannot be standardized because the essential differences in generator design require different lengths. As it was felt, however, that the same shaft-end can be standardized for both ends of such generators, the subject was referred back to the Subdivision for further consideration.

The action taken at the January Standards Committee meeting, referring back for further consideration the revision of the S.A.E. Standard for Generator-Flange Mountings, page B17 of the S.A.E. Handbook, recommended by the Electrical Equipment Division, was reviewed. It was stated that for ball-bearing installations there would be no advantage, but in fact the disadvantage of added cost for larger bearings, in changing the shaft diameter of the small size to that for the shaft diameter of the large-size flange. After discussion it was decided that no attempt should be made to standardize one shaft diameter for both sizes of generator flange.

Action was also taken towards changing dimensions *L* from 1-25/32 to 1-13/16 in. and dimension *M* from 1-15/16 to 2-1/32 in. as recommended by the Division in its report to the Standards Committee meeting last January. These changes were made so that the cotter-pin hole in the end of the shaft will provide for the standard overhang of the driving gear, a standard plain washer thickness and an S.A.E. Standard nut assembly. This subject was referred back to the Subdivision with instructions that a definite layout be made indicating the standard gear overhang and the plain washer thickness as a check on the changes proposed.

The suggestion that a flange mounting for outboard installation, but similar to the present starting-motor sleeve mounting, page B20 of the S.A.E. Handbook, should be adopted by the Society was submitted by the Subdivision. Sketches were shown of the layouts to be used with S.A.E. Standard flanges Nos. 1, 2 and 3, page B19 of the S.A.E. Handbook. It was decided to refer this entire subject back to the Subdivision with instructions to report proposed flange mountings having the same overall lengths and clearances as those shown on the present starting-motor sleeve-type mounting.

The Subdivision reported that since the S.A.E. Standard for Starting-Motor Flange Mountings, page B19 of the S.A.E. Handbook, had been changed from 13/32 to 7/16 in., a number of complaints had been received and that the Subdivision felt that an error was made in adopting the 7/16-in. diameter. General discussion indicated that the 13/32-in. hole should provide sufficient clearance for easy assembling, even in cases where the holes in the crankcase are not accurately drilled, and that the change had been made principally for tooling purposes and the selection of drill sizes in the shop. Action was taken recommending that the flange hole-diameters should be changed to agree with those originally adopted by the Society.

It was noted that in some installations it is necessary to assemble the starting motor in the flywheel case by using studs instead of bolts, because there is not room to get the bolts into the casting, but that the manufacturers do not know what length to make the studs because there is no standard thickness for the starting-motor flange. It was observed that in some generator mountings a gasket is used under the flange, but that it was not possible to design these gaskets to the same outline as the flange because some of the dimensions were lacking. It was decided to refer this matter to the Subdivision in order that a report might be formulated giving the maximum thickness for starting-motor and generator flanges and also complete dimensions for the contour of the generator flanges.

Blueprints were submitted showing a suggested mounting for airplane starting-motors used extensively at the present time by the Government and several airplane builders. It was felt that the whole situation with regard to airplane design is in such an unsettled condition that it would hardly be proper to adopt a particular type of starting-motor mounting at this time. It was therefore decided to hold this subject in abeyance until practice shall have become more established.

Ignition Distributor Mountings

The proposal to establish a definite dimension for the distance from the bottom of the Type-B distributor mounting barrel to the bottom of the tongue of the distributor half of the coupling was discussed at length at the April Electrical Equipment Division Meeting. It was felt that this dimension should be definitely established rather than leave it variable as now specified in the present S.A.E. Standard, page B16 of the S.A.E. Handbook. It was therefore recommended that this dimension be specified as 27/32 in. Changes in the bore tolerances for the distributor couplings, from 0.4930 in. maximum and 0.4920 in. minimum to 0.4915 in. maximum and 0.4905 in. minimum, were approved, as it was considered that the proposed tolerances will be satisfactory, their adoption eliminating as much looseness in this fit as possible.

Involute Splines

The subject of involute splines was tabled at the April meeting of the Parts and Fittings Division as it was felt that such standardization is not practical.

Magneto Mountings

The Electrical Equipment Division approved the Subdivision report on magneto mountings, published on page 300 of the April issue of The Journal, for submission to the Standards Committee in June as S.A.E. Recommended Practice. It was decided to include timing-lever dimensions in accordance with the present standard for motorcycle mag-

netos which specifies an advance-lever radius of 1.968 in. and a timing-lever hole-diameter of 0.2185 in.

The suggestion by L. F. Burger, of the International Harvester Co., that the flange type of magneto mountings for stationary engines should be standardized for applications where it is impossible to use the base-mounted type was discussed. The Division felt that this subject should be taken up and the following Subdivision was appointed to investigate and prepare a report on it:

A. D. T. Libby, chairman	Splitdorf Electrical Co.
W. F. Borger	International Harvester Co.
A. C. Kleckner	Webster Electric Co.
A. Rosner	American Bosch Magneto Corporation
F. L. Tubbs	Alamo Farm Light Co.

Motorboat Division Meeting

Real progress was made on several subjects at the Motorboat Division meeting on April 10, the first meeting since 1919.

It was brought out that standardization of voltage ratings would be of great assistance, present practice being such that many electrical devices are not manufactured in voltages that will permit their use on small motorboats. It was thought that the Motorboat Lighting Subdivision of the Lighting Division should consider the advisability of recommending the use of 12 volts for combination starting and lighting systems, and 32, 64 and 110 volts for separate lighting systems. The 32 and 110-volt ratings are now specified in the S.A.E. Recommended Practice for Voltage and Capacity Ratings for Isolated Electric Lighting Plants, page B37 of the S.A.E. Handbook.

It was thought that the present S.A.E. Standard for Motorboat Transmission Couplings, page E7 and E15 of the S.A.E. Handbook, should be revised, particularly in reference to the nuts necessitated by the design of certain couplings. L. Ochtman, Jr., was appointed a Subdivision of one to review these standards and to report any necessary revisions at the next meeting.

L. Ochtman, Jr., was appointed also to serve as chairman of a Subdivision to obtain information on tachometer-drive practice, as it was felt that this is a very important subject for standardization, present practice being such that charges for installing tachometers are extremely high.

The suggestion that the control levers that come as part of the engine equipment should be standardized so as to permit the use of such levers in connecting the bridge-deck controls was discussed. It was stated that present practice is such that in most cases the levers supplied by the engine builders must be thrown away as they are not suitable for the usual installations. F. B. Sexton was appointed a Subdivision of one to study this problem and report at the next meeting.

Chairman VanBlerck said that previous work of the Division showed that there was absolutely no uniformity of practice as to the height of the engine support arms from the center-line of the crankcase. It was thought that standardization should be limited entirely to medium-duty and high-speed engines for pleasure craft, inasmuch as heavy-duty engines for commercial boats are much wider and are not as a rule replaced. It was thought that any standardization should be based on the engine bore, stroke and speed, rather than the horsepower which varies to a great extent for the same bore, stroke and speed. Mr. Sexton was appointed a Subdivision to obtain information on present practice and report back at the next meeting.

It was also thought that information should be obtained as to the location of the exhaust pipe.

It was argued that the engine rotation should be standardized and the Standards Department was instructed to obtain information on present practice.

It was brought out that present practice for stuffing-boxes varies to a very great extent. It was considered that the length of the stuffing-box depends entirely upon the diameter of the shaft. William J. Deed was appointed a Subdivision to formulate a report on this subject for presentation at the next Division meeting.

The standardization of diameter tolerances for propeller shafting was discussed. It was understood that Vice-Chairman Brautigam would communicate with W. H. Bassett, of the American Brass Co., a member of the Non-Ferrous Metals Division, as to the advisability of the Non-Ferrous Metals Division formulating a specification covering propeller shafting.

Nomenclature Division Meeting

The extension of the present S.A.E. Standards for Automobile Nomenclature to cover all automotive apparatus was undertaken at the meeting of the Nomenclature Division on April 3. The automotive industry was divided into the following seven general groups as a basis upon which to work:

Aeronautics	Power Farming
Highway Transport	Stationary-Engine
Industrial Service	Operation
Motorcycling	Water Transport

These general groups were subdivided into the main types of apparatus belonging to each and the types further divided into sub-classifications. Sub-divisions were appointed to consider each of the general groups and to prepare complete tentative nomenclatures. It was understood that each Subdivision would be enlarged by the Sub-division chairman in order that qualified men might cooperate in drafting the nomenclature for the various types of apparatus.

Pipe Fittings

F. G. Whittington and W. H. Hollister have been appointed a Subdivision to review the present S.A.E. Recommended Practices for fuel and lubricating pipe fittings, for both soldered and compression types, pages C46 and C47 of the S.A.E. Handbook.

Plate Glass

The Passenger-Car Body Division Subdivision on Plate Glass is cooperating with a committee organized by the Bureau of Standards on which is represented the American Institute of Architects, the Treasury Department, the Bureau of Standards, the Glass Distributors Association, the Plate Glass Manufacturers Association, the Sash and Door Association and window and wire-glass manufacturers.

Roller Chains

At the January Standards Committee Meeting the minimum breaking-strength recommended for adoption by the Chain Division was discussed at length by several members of the Committee. This discussion was printed on page 121 of the February issue of The Journal.

The criticisms brought out in this discussion were carefully considered by the Technical Subcommittee on Chains and Sprockets, and the following points have been agreed upon by the engineers of the principal manufacturers of roller transmission chains in this country.

(1) The selection of a chain for power transmission should not be based upon the breaking strength, but upon the allowable *working load* for the conditions of the drive

(2) Designers who wish to know the approximate breaking-strength of a chain have a right to that information, and chain makers are willing to give it, *provided* they can protect themselves against those who, through ignorance, insist upon selecting their chains solely on the basis of breaking strengths

(3) The publication of a variety of strengths for chains of the same class is misleading to many buyers, and creates the impression that chain makers are vying with one another with respect to this feature that the buyers seem to regard as of first importance in the attainment of the highest quality

(4) Chain makers are therefore in favor of publishing minimum breaking-strengths, with the understanding that, although the average strengths will run much higher, they will not be guaranteed; nor are they considered necessary, since the published mini-

mum-strengths are four or five times as high as the maximum published working loads

(5) If one chain maker adds 10 or 15 per cent to the ultimate-strength of his chain without increasing the pin bearing area or the wearing quality of the parts, the allowable working load will not be increased, and his chain will not be capable of transmitting any greater horsepower. This increase in strength will generally be at the expense of light weight, or of the desirable shock-absorbing quality, or of the tight grip between assembled parts. Hence a publication of this feature will tend to mislead the innocent and unwary who are inclined to base their selection of a chain upon breaking strength alone

(6) The advance of the chain drive as an efficient and durable medium for the transmission of power requires that misconceptions be abolished, and that the attention of chain users be drawn away from the non-essentials, such as breaking-strength and polished side-plates, and fixed upon the essentials, such as working loads, speeds, number of teeth and sprocket tooth-forms

(7) The publication of uniform minimum breaking-strengths for standard chains is a step in this direction

Spring Shackle-Bolts

A Subdivision report on Spring Shackle-Bolts was submitted at the meeting of the Parts and Fittings Division in April. It is expected that this report will be finally approved at the May Division meeting and submitted for consideration at the meeting of the Standards Committee in June.

Springs Division Meeting

At the Springs Division meeting on March 14 Chairman Hess stated that it is generally felt among spring manufacturers that the S. A. E. Springs Division could do much in the way of revising existing standards and developing new ones for the spring industry. As it was thought that the best way to accomplish this is by assigning the work to Subdivisions, each Subdivision to hold meetings as frequently as necessary for the preparation of reports on the several subjects assigned to them, the following Subdivisions were appointed and subject assignments made:

SUBDIVISION A

Personnel

H. R. McMahon, chairman	Standard Steel Spring Co.
E. S. Corcoran	Kelly-Springfield Motor Truck Co.
E. V. Rippingille	Watson Stabilator Co.

Subjects Assigned[1]

Leaf-Spring Nomenclature, H1 and H2
Leaf Points, H2
Lubricating of Springs
Prime Painting of Springs
Spring Rebound Clips, Spacers and Bolts, H3
Spring Center-Bolts, H4
Finish of Springs, H2

SUBDIVISION B

Personnel

S. P. Hess, chairman	Detroit Steel Products Co.
W. M. Newkirk	William & Harvey Rowland, Inc.
R. S. Begg	Jordan Motor Car Co.
F. A. Whitten	General Motors Truck Co.

Subjects Assigned[1]

Spring Specifications, H10 to H19
Motor-Vehicle Manufacturers Specifications
Spring Manufacturers Data
Recommended Assembly Practice
Outgoing and Incoming Inspection
Flexibility Test
Capacity Test
Brinell and Transverse Bend Tests
Shrunk Center-Bands

[1] Numbers refer to S.A.E. HANDBOOK page references.

SUBDIVISION C

Personnel

H. E. Figgie, chairman	Perfection Spring Co.
Gustof Peterson	Electric Alloy Steel Co.

Subjects Assigned[1]

Wrapped Spring-Eyes, H4
Test for Parallelism of Spring-Eyes, H5
Spring-Eye Bushing and Bolt Tolerances, H5
Width of Spring-Ends, H6
Frame Brackets for Springs, H6
Spring Offsets and Resulting Ends, H7

It was thought advisable to define adequately terms commonly used by the spring industry, in a manner similar to that followed in the Iron and Steel Standards recently adopted. It was stated that there is some confusion as to the difference in meaning between spring "deflection" and "displacement." Mr. McMahon was requested to prepare definitions for these two terms for consideration at the next meeting.

There was some discussion as to establishing a new standard for the finish of springs, but it was stated that, as the present designations cover practically all leaf-spring practice, any other kinds of finish should be considered special.

It was suggested that a standard should be formulated for practice in lubricating leaf-springs when shipped from the maker to the buyer. It was explained that some purchasers require their springs shipped lubricated, while others order them dry, and that in most cases where springs are lubricated this interferes with their painting when assembled in the vehicle. It was therefore decided not to attempt to standardize this practice, but to request the Lubricants Division to suggest which type of lubricant is best for leaf-springs.

The Division discussed at some length the desirability of specifying a standard priming-coat of paint for leaf springs inasmuch as this practice seems to be growing. It was thought that it would be practically impossible to develop a satisfactory standard specification for priming paint and that the best method of handling this subject is to provide for information on spring specification sheets as to whether or not springs should be given a priming coat.

Attention was given also to the possibility of specifying the color of the priming coat, but it was decided that this should be left to the paint manufacturer and spring maker.

It was generally agreed that a "Spring Makers' Information Sheet," on which definite complete data can be uniformly recorded for all purchasers, is very desirable. It was decided that Subdivision B should give this matter further consideration and draft such a sheet for inclusion in the S. A. E. Standard for "Spring Specifications."

As it has been found that many vehicle builders do not exercise proper care in assembling springs in vehicles, it was decided that Subdivision B should consider this subject and draft a brief set of instructions to be included under "Spring Specifications."

The troubles experienced by spring makers due to inspection methods and the rejection of springs was discussed and it was thought that definite information in this connection could be published to advantage. This subject was therefore referred to Subdivision B for study.

The present standard flexibility tests were discussed and, as it was thought they could be materially improved, the subject was referred to Subdivision B for further consideration.

Mr. McMahon stated that the subjects of Brinell and Transverse Bend Tests, which were discussed by the Iron and Steel Division some time ago, are of importance to the spring manufacturers and that he is now working closely with one of the large automobile companies in the development of such tests.

It was proposed that the threads specified for the S. A. E. Standard for Spring Center-Bolts should be changed from S. A. E. to U. S. Standard because trouble had been experienced through the stripping of the S. A. E. threads. Chairman Hess reviewed the consideration of this matter by the Division several years ago and stated that it would be a mis-

take to go back to the U. S. Standard. It was decided to refer this matter to Subdivision A for further study.

The objections raised by vehicle builders on a number of occasions to the present tolerances for parallelism were reviewed and discussed, the thought being advanced that the same tolerances should be specified for truck and passenger cars, it being largely the function of the spring maker to maintain these tolerances. It was stated that much of the trouble is due to misalignment of axles and frames, which interferes with easy assembly of springs even when the parallelism tolerances are maintained. The subject was referred to Subdivision C for an investigation of tolerances that are allowed on frames and axles and a reconsideration of the spring parallelism tolerances.

As it was felt that the S. A. E. Recommended Practice for Spring-Eye Bushing and Bolt Tolerances should not specify tolerances for any of the bolts inasmuch as these tolerances should be controlled by the bolt manufacturers in accordance with the tolerances set for the bolt-holes, it was voted to omit this part of the specification. It was stated that the present S. A. E. Recommended Practice for Spring Frame Brackets is neither complete nor uptodate and that it is logically a subject affecting the frame rather than the spring manufacturer. It was therefore decided to recommend that the present recommended practice on page H6 of the S. A. E. HANDBOOK be cancelled and to refer this subject to the Frames Division.

It was suggested that the length of rear springs for car weights of less than 2500 lb. should be increased because the stiffness of springs has decreased about 40 per cent during the past four years and longer springs are needed to obtain proper riding qualities. This subject was referred to Subdivision C for further consideration.

WIRE MESH

As information on present wire-mesh usage indicates a wide range of practice, a Subdivision of the Parts and Fittings Division has been appointed to prepare a report on its standardization. It is thought that the present range of wire sizes and meshes can be considerably reduced, and that a standard can probably be established for the kind of weave, sizes of wire and mesh, with possibly a supplementary table showing the percentage of opening per square inch for each mesh. The following Subdivision was appointed:

Clarence Carson, chairman	Dodge Bros.
E. W. Weaver	Weaver & Kemble

THE ALLIED DEBTS

IT was in the spring of 1919 that the payment of principal and interest on the Allied debts was suspended. The suspension was literally forced by the increasing gravity of the international situation. Europe has been purchasing American goods, for which she has been unable to pay except with funds from our own pocket. By private loans, the repurchase of securities held abroad and direct credits by our Government, we had advanced some $13,000,000,000 to finance these necessary purchases of our goods by Europe. When in the spring of 1919 the foreign exchanges were unpegged, and our Government ceased its advances of credit, the foreign exchanges fell heavily. Despite the violent dislocation of the exchange machinery, the extraordinary flow of goods to Europe continued, our exports in 1919 and 1920 being the largest in our history. Nothing could indicate more clearly the continued need of Europe for American help. So great has been Europe's need that her importers have had to be carried on short time by our exporters and bankers, the extent of this floating indebtedness being probably not less than $1,500,000,000 at the present time. In other words, far from Europe's being able to make interest payments on debts incurred during the war period, we have had conclusive proof of Europe's inability to pay even for her current purchases. Until this situation changes it is idle to suppose that Europe can undertake an annual payment of $550,000,000 on the Allied debt to us in addition to her payments for her current imports, interest on private loans and other obligations that have been incurred at various times.

Even if Europe could pay at this time, it is doubtful whether the American people would be prepared to accept the payment. Despite the numerous explanations given by the economists in recent years, there apparently still lingers in the public mind the fallacy that a payment from nation to nation is not materially different, in form and consequences, from a payment by one individual to another. It is a commonplace of economics that any large international payment ultimately must be made in goods. Our studies of the balance of payments of the United States have indicated conclusively that the resumption of the interest payments on the Allied debts would cause our export balance to disappear.

That the overturn of our trade balance is not in itself undesirable is amply proved by the experiences of Great Britain and Germany in the two or three generations preceding the war. Though they had a large unfavorable balance of trade, representing the earnings of their foreign investments, of the merchant marine and other sources of income, the large imports did not prevent their building up the largest export trade possessed by any nation of the world. This is a sufficient answer to the fears so commonly expressed in this country that European payments of interest, even at some future time, would flood our markets with foreign goods and ruin our export trade. Granting, however, that an eventual excess of imports need possess no terrors for us and might indeed be eminently desirable, we may well ask ourselves whether we wish to see this change occur suddenly, without proper opportunity to adjust our industry to it.—J. H. Williams in *Journal of American Bankers Association.*

ACTIVITIES OF THE SECTIONS

(*Concluded from page* 432)

entitled Some Notes on Motor Trucks. Mr. Myers treated several topics, among these being truck chassis lubrication, comparative wear of tires mounted on wood and on steel wheels, and the possibilities of rear-axle standardization. A lively and valuable discussion was had.

On May 25 the Pennsylvania Section will either hold an outing at Torresdale or a Body Engineering Meeting.

Mid-West Section—The subject of the Mid-West Section meeting of April 14 was Commercial Fuels. W. O. Hinkley, of the Peoples Gas Light & Coke Co., read the principal paper, the title of this being Actions and Results of Benzol as an Automotive Fuel. In another paper the use of alcohol as an automotive fuel was considered. The discussion following the two papers waxed hot at times but all present enjoyed the meeting and obtained a more intimate knowledge of the characteristics of motor fuels.

The results of the balloting for officers of the Section were announced, the large percentage of the Section members voting being gratifying as indicating their real interest in the Section's affairs.

At the May 12 meeting of the Mid-West Section Fundamental Losses in Automotive Apparatus will be discussed.

Applicants *for* Membership

The applications for membership received between March 18 and April 15, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABBEY, FRANK GORDON, student, Ohio State University, *Columbus, Ohio.*

ADAMS, CONRAD A., assistant professor of mechanical engineering, Tufts College Engineering School, *Tufts College, Mass.*

ALLEN, STANLEY C., experiment engine laboratory, Reo Motor Car Co., *Lansing, Mich.*

BACHLE, ANDREW, vice-president engineering division, Paige Detroit Motor Car Co., *Detroit.*

BAYERLINE, J. GEORGE, president and general manager, Columbia Motors Co., *Detroit.*

BERKOWITZ, SAMUEL, president and engineer, Automotive Products Corporation, *Hazleton, Pa.*

BISCHOFF, HAL C., lecturer and instructor, Sweeney Automobile and Tractor School, *Kansas City, Mo.*

BOCZ, ALEX J., mechanical engineer and designer, 2169 Richton Avenue, *Detroit.*

BOYER, RALPH L., student, Ohio State University, *Columbus, Ohio.*

BROOCK, HAROLD, 80 Longfellow Avenue, *Detroit.*

BROWN, JOHN W., general manager, John W. Brown Mfg. Co., *Columbus, Ohio.*

BROWNING, WILLIAM E., civilian instructor, Air Service Mechanics School, Chanute Field, *Rantoul, Ill.*

BUCHER, CLARENCE DEAN, student, Ohio State University, *Columbus, Ohio.*

BURTON, ROBERT B., chief draftsman, Rolls-Royce of America, Inc., *Springfield, Mass.*

CARTWRIGHT, ROBERT F., student, New York Telephone Co., *New York City.*

CASTLE, D. W., instructor, Y. M. C. A., *Omaha, Neb.*

CATE, GARTH W., general manager, Flexo-Motive Corporation, *Chicago.*

CHASE, IRWIN, chief engineer, Elco Works, *Bayonne, N. J.*

CHESEBRO, C. M., chief engineer, Detroit Motor Co., *Washington, Pa.*

CLARK, OLIVER H., body engineer, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

COBB, CARROLL J., student, Ohio State University, *Columbus, Ohio.*

COFFEY, HARRY L., draftsman, 716 West Front Street, *Plainfield, N. J.*

COOK, HARMON J., works manager, Standard plant, Torrington Co., *Torrington, Conn.*

CRISSMAN, IRA STANLEY, wheel engineer, Disteel Wheel Corporation, *Detroit.*

DUBAY, BARTON E., engine draftsman, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

EBY, EARL E., service manager, Remy Electric Co., *Anderson, Ind.*

FELBECK, GEORGE T., research assistant, University of Illinois, *Urbana, Ill.*

FORREST, CLIFFORD L., student, Ohio State University, *Columbus, Ohio.*

FRANKLAND, EDWIN, master mechanic and tool engineer, General Motors Truck Co., *Pontiac, Mich.*

GARRISON, R. L., student, Agricultural College of Utah, *Logan, Utah.*

GIRDWOOD, R. F., automobile sales manager and engineer, Ledoux, Jennings, Ltd., *Montreal, Canada.*

HADLEY, NEWTON F., engineer, Willys Corporation, *Elizabeth, N. J.*

HARRIS, FIRST-LIEUT. HAROLD R., Air Service, McCook Field, *Dayton, Ohio.*

HAWLEY, B. T., engineer, Holt Power Light Co., *Detroit.*

HEMEON, J. RUSSELL, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

HENDRICKS, L. R., instructor, Youngstown Institute of Technology, *Youngstown, Ohio.*

HULET, LEROY E., 1744 Coventry Road, *Cleveland Heights, Ohio.*

JOHNSON, C. MORRISON, student, University of Washington, *Seattle, Wash.*

KAISER, AUGUST, body designer and draftsman, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

KAUFFMAN, ALFRED, vice-president and general manager, Link-Belt Co., *Indianapolis.*

KELLER, ALEX W., assistant to general superintendent, Atlas Powder Co., *Wilmington, Del.*

LEWENTHAL, ALLEN, service manager, Smith Motor Sales Co., *Phoenix, Ariz.*

LEWIS, ROBERT H., assistant superintendent, Maccar Truck Co., *Scranton, Pa.*

LINDECKER, JOSEPH BRIGHAM, student, Ohio State University, *Columbus, Ohio.*

LOMER, ROWLAND E., instructor, Motor Transport Training School, Camp Holabird, *Baltimore, Md.*

LYTLE, R. W., assistant chief engineer, Stephens motor works of Moline Plow Co., *Freeport, Ill.*

MCNAUGHT, A. STANLEY, assistant engineer, Clutha Works, *Glasgow, Scotland.*

MACLELLAN, W. ADAIR, assistant engineer, Clutha Works, *Glasgow, Scotland.*

MARKS, E. S., JR., assistant engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

MARTY, WILFRED N., assistant chief inspector, Wright Aeronautical Corporation, *Paterson, N. J.*

MILLER, HENRY J., draftsman, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

MOOSHRUGGER, JOSEPH, airplane structural designer, Dayton Wright Co., *Dayton, Ohio.*

OVERTON, CARL I., vice-president, Bassick Mfg. Co., *Chicago.*

PARKER, LINUS J., designer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

PERCY, LEON, general manager, Cooper Storage Battery Mfg. Co., *Madisonville, Ohio.*

PERRY, JAMES W., general manager automobile equipment and electrical departments, Johns-Manville, Inc., *New York City.*

RICHARDSON, HERMAN E., instructor, Motor Transport Training School, Camp Holabird, *Baltimore, Md.*

RODIER, EDWARD J., engineer and director of sales, Dempsey Cycle Co., *Philadelphia.*

ROESSINGER, HERBERT, chief engineer, Cleveland City Forge & Iron Co., *Cleveland.*

ROTHE, WALTER C., designer, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

SHERRIFF, S. S., chief road mechanic, Armour & Co., *Chicago.*

SIMPSON, THOMAS, managing director, Clutha House, Westminster, *London, England.*

SKELTON, O. R., vice-president, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

SKINNER, RALPH L., Skinner Automotive Device, *Sacramento, Cal.*

SOMERBY, CHARLES T., secretary and service manager, United Motor Car Co., *Trenton, N. J.*

SWEET, MAHLON E., partner and superviser of shop, Sweet Drain Automobile Co., *Eugene, Ore.*

TANNHAUSER, W. F., general manager, Mar Tan Motor Mfg. Co., *Milwaukee, Wis.*

TEXADA, G. P., engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

TILGHAM, RICHARD C., instructor, Motor Transport Training School, Camp Holabird, *Baltimore, Md.*

TOWLER, JOSEPH C., service manager Autolec Co., Inc., *Worcester, Mass.*

TUTHILL, LEON, shop superintendent, Reo Motor Car Co. of New York, *New York City.*

VOGEL, FRANK E., student, State University of Iowa, *Iowa City, Iowa.*

WAHLBORG, EWALD G., body draftsman and designer, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

WERDEHOFF, ALBERT B., chassis engineer, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

WHITE, ROBERT B., lubrication engineer, Taxman Refining Co., *Chicago.*

WICKENDEN, THOMAS H., engineer in charge of methods and specifications, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

WILCOX, MERRILL M., secretary and treasurer, Wilcox Motor Parts & Mfg. Co., *Saginaw, Mich.*

WILLIAMS, ARTHUR HOWARD, research engineer, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*

WINTER, PAUL H., chief draftsman, Maccar Truck Co., *Scranton, Pa.*

ZIMMERER, MARK EUGENE, assistant chief engineer, Kokomo Brass Works, *Kokomo, Ind.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between March 10 and April 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ADDAMS, CHARLES D. (A) sales engineer, Bearings Co. of America, *Lancaster, Pa.*

ANDERSON, ROBERT A. (A) general manager, Victory Hammered Piston Ring Co., *Newark, N. J.,* (mail) 282 South Street.

BARBECK, PETER (A) master mechanic, F. V. F. Machine Works, New York City, (mail) 134 Christopher Street.

BASSETT, CYRUS W. (A) sales engineer, Bethlehem Steel Co., *Bethlehem, Pa.,* (mail) 62 East Market Street.

BAYBUTT, JOHN W. (J) draftsman, Selden Truck Corporation, *Rochester, N. Y.,* (mail) 16 Seneca Park Circle.

BEAUCHAMP, STAFFORD D. (E S) student, Georgia School of Technology, *Atlanta, Ga.,* (mail) 214 Forrest Avenue, Apartment 4.

BISHOP, WALTER W., JR. (J) test engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 815 Grand Avenue.

BUGGIE, HORACE H. (A) vice-president and general manager, Dura Mechanical Hardware Co., *Toledo,* (mail) 2280 South Albion Street.

BURTNETT, EVERETT R. (A) 5912 Woodlawn Avenue, *Los Angeles.*

BUS TRANSPORTATION (Aff) 10th Avenue and 36th Street, *New York City.*
Representative: Carl Stocks, managing editor.

CARSON, RAY EDGAR (E S) student, Purdue University, Lafayette, Ind., (mail) 406 North Ellsworth Street, *West Lafayette, Ind.*

CHRISTIANSEN, SVEND A. (J) test engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 211 East Herman Avenue.

CLINE, N. N. (E S) student, Purdue University, Lafayette, Ind., (mail) 209 North Street, *West Lafayette, Ind.*

COOPER, M. S. (A) vice-president and sales manager, Asbestos & Rubber Works of America, Inc., New York City, (mail) 214 West 59th Street.

DONAHEW, A. L. (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 126 Sheetz Street.

DRAPER, HOWARD W. (A) supervisor of automotive courses, Franklin Union, Boston, (mail) 1 Bunton Park, *East Milton, Mass.*

EBERTS, JOHN FOSTER (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 205 South Sixth Street.

EDDISON, W. BARTON (M) consulting engineer, New York City, (mail) *Ardsley-on-Hudson, N. Y.*

EYERLY, L. U. (A) automotive engineer, 246 State Street, *Salem, Ore.*

FAUNTLEROY, HERMANZE EDWARD (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 1732 Salem Street.

FAY, CHARLES R. (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 129 South Grant Street.

FISCHER, KARL W. (A) repair foreman, Detroit Cadillac Motor Car Co., New York City, (mail) 1277 Shakespeare Avenue.

FRASER, WILLIAM R. (A) service manager, Henry W. Peabody & Co., Bolivar 1650, *Buenos Aires, Argentina,* (mail) Cramer 2210.

GLEN, WALTER A. (M) president and manager, Four Wheel Drive Auto Co., *Clintonville, Wis.,* (mail) 46 West Eighth Street.

GOUDY, CARL F. (A) instructor, Pratt Institute, *Brooklyn, N. Y.,* (mail) 92 Gates Avenue.

GRABNER, JOHN (E S) student, Purdue University, Lafayette, Ind., (mail) 522 Northwestern Avenue, *West Lafayette, Ind.*

GRAPE, THEODORE S. (A) manager and proprietor, Bearings Sales Co., 1919 14th Street, N.W., *City of Washington.*

GRISELL, LOWELL HOBART (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 205 South Sixth Street.

GUTEKUNST, HERMAN (A) assistant chief engineer, Ray Battery Co., *Ypsilanti, Mich.*

HAMILTON-GRAPES, G. (F M) 501 Elizabeth Street, *Melbourne, Australia.*

HARPER, ROBERT D., 3RD (S M) physicist, Bureau of Standards, City of Washington, (mail) 4 West Irving Street, *Chevy Chase, Md.*

HAYES, HAROLD W. (M) division engineer, Dodge Bros., *Detroit,* (mail) 293 East Canfield Avenue.

HAZEN, RONALD MCKEAN (E S) student, University of Michigan, *Ann Arbor, Mich.,* (mail) 321 South Division Street.

HEATON, HOWARD H. (E S) student, Purdue University, Lafayette, Ind., (mail) 224 Vine Street, *West Lafayette, Ind.*

HOLMES, H. GLENN (M) chief engineer, Novo Engine Co., *Lansing, Mich.* (mail) 909 North Capitol Avenue.

HOPKINS, PETER A. (M) mechanical engineer, Penn Spring Works, *Baldwinsville, N. Y.*

HOYNE, BLANCHARD HERBERT (E S) student, Purdue University, Lafayette, Ind., (mail) 420 Harvey Avenue, *West Lafayette, Ind.*

HUBBARD, LEWIS EDWARD (E S) student, Purdue University, Lafayette, Ind., (mail) 356 State Street, *West Lafayette, Ind.*

JENKINS, JESSE MORTON (E S) student, Purdue University, Lafayette, Ind., (mail) 120 Wood Street, *West Lafayette, Ind.*

JOHNSON, E. F. (A) general manager, intercompany parts division, General Motors Corporation, General Motors Building, *Detroit.*

KEITH, ROBERT R. (M) superintendent, International Harvester Co., Chicago, Ill., (mail) 89 North Grant Street, *Hinsdale, Ill.*

KUKELKORN, GEORGE A. (A) final inspector, Cadillac Motor Car Co., New York City, (mail) 323 East 144th Street.

LEHMAN, HAROLD E. (M) engineering department, Stutz Motor Car Co. of America, Inc., *Indianapolis,* (mail) 4205 North Illinois Street.

LITTLEFIELD, L. H. (A) engineer, Barsdall Refining Co., 340 New York Life Building, *Kansas City, Mo.*

MARVIN, CHARLES FREDERICK, JR. (E S) student, Ohio State University, *Columbus, Ohio,* (mail) 384 West Eighth Avenue.

MILLER, ALBERT H. (M) research engineer, Midvale Steel & Ordnance Co., *Philadelphia,* (mail) P. O. Box 1322.

NIGG, H. N. (A) vice-president and general manager, Detroit Bevel Gear Co., *Detroit.*

NUTT, ARTHUR (M) chief engineer of engines, Curtiss Aeroplane & Motor Corporation, *Garden City, N. Y.*

PERLOV, A. P. (J) 1373 St. Johns Place, *Brooklyn, N. Y.*

RAWLINS, EDWARD B. (J) draftsman, C. & G. Cooper Co., *Mount Vernon, Ohio,* (mail) 210 East Burgess Street.

REIHMER, LEO LESTER (E S) student, Armour Institute of Technology, *Chicago,* (mail) 1829 South 48th Court.

RICE, HERBERT H. (A) president and general manager, Cadillac Motor Car Co., *Detroit.*

RIEGER, NELSON MILES (E S) student, Ohio State University, Columbus, Ohio, (mail) 40 Wistaria Drive, *Dayton, Ohio.*

RITZI, HARRY (E S) student, Purdue University, *Lafayette, Ind.,* (mail), 459 North Grant Street.

SCHAD, ALFRED BARTH (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 816 North Street.

SCHAKEL, RAYMOND ANTON (E S) student, Purdue University, Lafayette, Ind., (mail) 690 Waldron Street, *West Lafayette, Ind.*

SCHLAFMAN, CLIFFORD JACOB (E S) student, Ohio State University, *Columbus, Ohio,* (mail) 1928 North High Street.

SHIBATOH, TADAICHI (F M) chief engineer and factory manager, Japan Automobile Co., Tameike, Akasaka, *Tokio, Japan.*

SODERHOLM, CAPT. WALTER H. (A) Ordnance Department, *Rock Island Arsenal, Ill.*

SOLBRIG, H. E. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 203 University Street.

SIKOROVSKY, E. J. (A) division superintendent, American Car & Foundry Co., 2503 South Wood Street, *Chicago,* (mail) 2717 South Springfield Avenue.

STEEN, ADOLPH F. (E S) Purdue University, *Lafayette, Ind.*, (mail) 156 North Grant Street.

SWEET, WILLIAM M. (A) vice-president, Klaxon Co., *Bloomfield, N. J.*

TAYLOR, JAMES RUSSELL (E S) student, Purdue University, Lafayette, Ind., (mail) 175 Littleton Street, *West Lafayette, Ind.*

THOMAS, THEODORE PAUL (E S) student, Purdue University, Lafayette, Ind., (mail) 234 Littleton Street, *West Lafayette, Ind.*

THUM, WILLIAM CLARK (J) 2441 Haste Street, *Berkeley, Cal.*

TREE, RUSSELL M. (A) technical supervisor, American Brass Co., *Kenosha, Wis.*

TROAKE, SAMUEL S. (A) chief inspector, Detroit Cadillac Motor Car Co., *New York City,* (mail) 299 East 162nd Street.

TUFFORD, HENRY HORACE (A) manager of tire instruction and supervisor of tire department, Dunwoody Institute, *Minneapolis,* (mail) P. O. Box 673.

VAN ZANDT, FIRST-LIEUT. J. PARKER (S M) Air Service, McCook Field, *Dayton, Ohio,* (mail) Army and Navy Club, *City of Washington.*

WENDELL, EVERT J. (M) chief engineer and manager, Hale Fire Pump Co., Inc., Conshohocken, Pa., (mail) *Wayne, Pa.*

WHITE, HERBERT R. (A) general sales manager, Lancaster Steel Products Corporation, *Lancaster, Pa.*

WILLIAMS, GURDON HUNTER (E S) student, Columbia University, *New York City,* (mail) 421 West 117th Street.

WILLIAMS, R. A. (A) assistant supervisor, Texas Co., *Norfolk, Va.*, (mail) 737 Redgate Avenue.

WINKLER, WILLIAM (A) owner, Winkler Motor Service, *Chicago,* (mail) 314 North Dearborn Street.

WITHEROW STEEL Co. (Aff) *Pittsburgh.*
Representatives: W. P. Witherow, president,
G. R. Norton, steel works manager.

WOOD, HENRY M. (M) secretary, Trailmobile Co., *Cincinnati.*

WOOD, R. M. (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 130 McLennon Avenue.

WRIGHT, WARREN O. (M) assistant chief engineer, Bowen Products Corporation, *Auburn, N. Y.*, (mail) 24½ Gaylord Street.

THE

JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE ENGINEERS

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 *W.* 39*th St., New York*

Issued monthly, $1 a number, $10 a year; foreign $12 a year; to members, 50 cents a number, $5 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1918.

B. B. BACHMAN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. X JUNE, 1922 No. 6

INDEX

Activities of the Sections		535
Airplane Performance Formulas—Edward P Warner		469
Applicants for Membership		537
Applicants Qualified		538
Automatic Charging of Motive-Power Storage-Batteries—H M Beck		499
Chronicle and Comment		443
Cooperative Farm Marketing		462
Detonation Characteristics of Some Blended Motor-Fuels—Thomas Midgley, Jr., and T A Boyd		451
Facility of Association		534
Farmer's Reward		456
Flighty Reflections—C L Egtvedt		466
German Export Trade		450
Index		539
May Council Meeting		508
Method of Developing Aircraft Engines—Capt G E A Hallett		457
New System of Spring-Suspension for Automotive Vehicles—H M Crane		463
Obituaries		534
Oil Consumption—A A Bull		513
Oil-Pumping—G A Round		509
Overhead Camshaft Passenger-Car Engines—P M Heldt		489
Personal Notes of the Members	Adv Section	2
Reports of Divisions to Standards Committee		475
Research Topics and Suggestions		507
S A E Employment Service	Adv Section	58
Standardization		450
Summer Meeting		445
Test Apparatus for Propeller Models		534
Welfare Work		468

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. X June, 1922 No. 6

Chronicle and Comment

June Council Sessions

THE Council of the Society will hold a meeting at White Sulphur Springs on Monday, June 19. This will be a regular session. A special session will be convened on the following afternoon for the purpose of attending to unfinished or new business, including consideration of the action taken by the Standards Committee on Tuesday, June 20.

Part II 1920 Transactions

COPIES of the forthcoming part of TRANSACTIONS, Part II of Vol. 15, will be distributed by parcel post early this month to the members who have ordered them. The issue contains about 40 papers and reports, together with the discussion thereon, presented at the 1920 Summer Meeting of the Society and at various meetings of the Sections.

Hoover on S. A. E. Standards

THE S.A.E. HANDBOOK appears to be a very complete example of the sort of technical standardizations that would greatly decrease our industrial wastes if they could be properly applied to our industries. Through our Division of Simplified Practice we hope to aid in these applications and it seems that we can be of special service in the automobile field.—Herbert Hoover, Secretary of Commerce.

The Mechanism of Lubrication

THE paper by Robert E. Wilson and D. P. Barnard, 4th, presented at the Annual Meeting and to be printed in an early issue of THE JOURNAL, should be of unusual interest to all engineers who have made a study of the subject of lubrication. The authors give only a very brief review of the classical theory of lubrication, and follow this with a very illuminating and practical discussion of some recent developments.

Among other things, they state that the coefficient of friction of a plain bearing depends upon a definite relation between speed, viscosity and bearing pressure and not on any one of these independently. The simple expression for this relation, which is $f = k z N/p$, where f denotes the coefficient of friction, k is a factor of proportionality, z the coefficient of viscosity, N the speed and p the bearing pressure, can be made very useful in designing bearings and detecting their shortcomings.

The authors explain what is meant by oiliness of lubricants; show why nearly all friction-machine tests have omitted this factor, and promise a future paper covering new work from the Massachusetts Institute Laboratory on this subject.

1922 Roster

COPIES of the printed Roster of the Society as of April 1 were forwarded last month to members who had ordered them. This book of 358 pages, issued in paper-bound form in accordance with long-standing practice, is of course of considerable value to the members in their work, especially in connection with traveling and correspondence. It contains lists of members arranged alphabetically and geographically and a list of the companies with which the members are associated, as well as the names of the officers and committeemen of the Society and of its representatives in other organizations, and statistical information with regard to classification and residence of the members.

Current Standards Reports

TWELVE Divisions of the Standards Committee of the Society will submit recommendations on 33 different subjects at the meeting of the Society to be held this month. The various recommendations relate to engineering practices in the agricultural equipment, electrical equipment, internal-combustion engine, iron and steel, lubricants, non-ferrous metals, parts and fittings and passenger-car body fields. Most of the matters submitted for review involve new standards, but 10 revisions of and 6 extensions of present standards are recommended. The cancellation of one standard is to be considered; and one progress report will be made. The reports of the respective Divisions are printed in this

issue of THE JOURNAL and a comprehensive discussion of them at White Sulphur Springs is desired.

Society Nominating Committee

THE Nominating Committee of the Society consists of members elected by the Sections, each Section naming one man and an alternate, and three members of the Society elected at the business session of the Semi-Annual Meeting of the Society preceding the Annual Meeting at which the officers are elected. Obviously, the committee is charged with the conduct of work of fundamental importance to the Society. The following have been named for service on the 1922 Committee by the Sections:

Section	*Member*	*Alternate*
Buffalo	A. A. Gloetzner	F. W. Gurney
Cleveland	R. J. Nightingale	W. R. Strickland
Dayton	V. G. Apple	L. S. Keilholtz
Detroit	Howard A. Coffin	T. J. Litle, Jr.
Indiana	Mark A. Smith	W. G. Wall
Metropolitan	Cornelius T. Myers	Finley R. Porter
Mid-West	B. S. Pfeiffer	Taliaferrc Milton
Minneapolis	L. A. Emerson	
New England	Leon W. Rosenthal	Prof. E. P. Warner
Pennsylvania	T. F. Cullen	F. M. Germane
Washington	W. S. James	

The additional members of the committee are to be elected at White Sulphur Springs on the evening of June 20. Under the rules of the Society the committee will hold an organization session during the Semi-Annual Meeting, and in due course nominate members to serve as officers of the Society during 1923.

Engineering Training for Foreign Service

THE demand for the training of engineers in foreign languages comes at a critical hour. Engineering colleges are hard pressed to meet the demand for the time devoted to civic and economic training. At many of the leading schools it has been keenly felt that engineering students as a rule did not, by the language training given, acquire the ability to read foreign technical literature, much less to express themselves in a foreign tongue.

American engineers should be able to read foreign literature and to deal with foreigners in their own tongue. In connection with work abroad the need often arises for knowledge of a language never taught in school. In European trade Russian, in Asiatic trade Chinese, in Brazilian trade Portugese are languages that undoubtedly will be of great importance in the future. Yet, we can hardly think of teaching them to engineering students generally.

The thing to do, therefore, seems to be to develop in our students the ability to acquire knowledge rapidly and unaided in a new field when the need of such knowledge arises. This is, however, exactly the ability that our engineering schools leave undeveloped. Foreign schools and our graduate schools develop it; the latter, however, at a too late age. By excessive coaching, supervising and scheduling we kill rather than foster initiative and enterprise in our undergraduates. This, to my mind, is the cardinal defect in our American college education. We develop perhaps the most moral, generous and decent type of man in the world. And this must not be given up. But we suppress the quality without which we will not hold our own in technical or commercial competition with foreign nations.

If any cure is to be wrought in this matter, it must come through missionary work of business and of the United States Government. The students must be made to see the opportunities offered them in foreign service. They must be given concrete examples of the unusual possibilities in new and undeveloped fields, where highly trained men are scarce. They must be imbued with an enthusiasm for real individual achievement and for far-reaching work. American engineering students are high-grade material, but they are now being trained to be routine men and job-holders at home rather than to be energizers and vitalizers on a world scale. They must be given vision and self-reliance. Let us hope that business and the Government will see their duty in this matter and set to work on a missionary campaign at an early date.—Prof. C. A. Norman at Congress on Commercial Engineering.

Highway Research

THE ability of concrete slabs to withstand repeated stresses caused by the passage of heavy trucks is being investigated at three laboratories, it is reported by Director W. K. Hatt, of the Advisory Board on Highway Research. Dean Johnson, of the University of Maryland, has devised a machine by which concrete beams may be deflected a few thousandths of an inch at the rate of 200 times per min. Fundamental research of this kind is not only of value in highway research but throws new light upon the fundamental properties of materials.

The composition of asphalt mixtures that will be stable at widely varying temperatures is being investigated by H. S. Mattimore, of Pennsylvania. The Bureau of Public Roads has built a circular track that will be surfaced with several mixtures of bituminous materials and subjected to truck action to determine the cause and remedy of the waving of pavements, which last summer involved enormous maintenance costs. Another circular track will expose various concrete aggregates to the wear of traffic.

Dr. G. E. Ladd, of the Bureau of Public Roads, has completed a report on his study of corrugations in gravel roads in eight different States. Contrary to the general impression of drivers, these waves, which have been so expensive in the maintenance of roads and of vehicles, are from 25 to 35 in. in length, crest to crest, and have a maximum height of 1½ in. unless pitting and ravelling have begun. These corrugations, it is stated, arise from the action of motor vehicles. Generally in gravel roads they originate in the kick-back of surface materials arising from the spin of one or both of the rear wheels as they descend from a bounce over some obstacle or depression. Spring action has undoubtedly a contributing and modifying effect. Dr. Ladd determines the density of traffic at which such corrugations arise and a means of keeping them down.

The problem of the sand-clay or top-soil road, which must furnish the main transportation for large regions of the South Atlantic states, is being studied in Georgia and North Carolina. Prof. C. M. Strahan, of the University of Georgia, has developed data that serve to define the percentage of clay and coarse sand that will render these roads stable under a traffic that they can reasonably be expected to carry. The Bureau of Public Roads and the North Carolina Highway Commission also are investigating this type of road to determine the limit of traffic under which they can be maintained, and a means of improving and extending the life of the surface.

(*Concluded on page* 522)

The Summer Meeting

THERE is every reason to believe that the 1922 Summer Meeting at White Sulphur Springs will excel those of the past 2 or 3 years in point of attendance and general attractiveness. There can be no doubt that the meeting will be well attended, for the reservations have reached a total of 561 as this issue of THE JOURNAL goes to press. It is fortunate that two unusually fine hotels are available at White Sulphur Springs with sufficient capacity to house the members comfortably. Many pleasant rooms will be at the service of the late-comers but it is the safest plan to send in reservations as far in advance of the meeting as possible. A reservation blank was printed on page 70 of the May issue of THE JOURNAL and another copy was included with a recent issue of the *Meetings Bulletin*. All applications for reservations *mailed before June* 15 should be addressed to the Society office in New York City, but after that date they should be addressed to the Society's Headquarters, White Sulphur Springs, W. Va. The blanks must be accompanied by a check to cover the necessary reservation and guest fees.

General Plan of Meeting

The general meeting plan that has proved so successful in past summers will be followed in 1922. The mornings will be devoted to automotive engineering sessions at which valuable technical papers on problems of current interest will be presented and discussed. The afternoons are set aside for an elaborate program of sports and games, while the evenings will be spent watching the latest screen drama or one-stepping to the tune of a popular syncopated symphony. Dull moments will be non-existent at White Sulphur Springs, for the resort itself offers numerous attractive features to while away the fleeting hours, even though an elaborate program of entertainment were not provided.

First Day Devoted to Standards

The opening day of the Summer Meeting, Tuesday, June 20, will be the occasion of the semi-annual meeting of the Standards Committee. Morning and afternoon sessions will be held and the various Standards Committee Divisions will report their recommendations to the Committee for approval. The subjects to be considered cover a wide field and are worth careful study by those engaged in the manufacture of parts or materials affected by them. Objections to or constructive criticism of any of the proposals will be welcomed at this meeting. The complete group of reports is printed in this issue of THE JOURNAL. Following the voting on the standards reports, one or two brief addresses will be made on the value of engineering standards to industry. R. M. Hudson, of the United States Department of Commerce, has been selected by Secretary Herbert Hoover to tell something of the work that this government agency is fostering to reduce waste in industry through standardization.

B. B. Bachman, president of the Society, will address the members at the semi-annual Business Meeting, Tuesday evening. Reports of the standing committees, the Secretary and the Treasurer will be presented. The members-at-large of the Society Nominating Committee will be elected at this time to act with the Section delegates in the selection of a ticket of Society officers for the year 1923.

Motorbus and Aeronautic Sessions

Two technical sessions will be conducted simultaneously on Wednesday morning, June 21. They will be devoted to the Motorbus and Aeronautics respectively. G. A. Green will present a paper on motorbus design which will be based on the experience gained through his long association with this form of automotive transportation. Mr. Green's paper will deal principally with the factors affecting bus chassis and body design, indicating the major points of difference between motor truck and motorbus chassis construction. In his work with the Fifth Avenue Coach Co., Mr. Green has been fortunate in carrying the dual responsibilities of operator and designer. His paper, though written from the engineering viewpoint, reflects the practical experience of the operator on the street. The paper which R. E. Plimpton will read at the Motorbus Session will set forth accepted bus design practice as evidenced by the models being currently built by motorbus manufacturers. Mr. Plimpton will make an analysis of the types of service the motorbus is expected to fill and indicate the designs best suited to each. Because of the rapid expansion of the motorbus arm of transportation, it is natural to expect

an active and valuable discussion after the presentation of these two papers.

Prof. E. P. Warner, of the Massachusetts Institute of Technology, has contributed a paper on the mathematical prediction of airplane performance which he will read at the Aeronautic Session. Professor Warner has derived simplified formulas that will serve the airplane designer in estimating such performance factors as minimum and maximum speed, rate of climb and the ceiling of a plane. Values obtained from these formulas were checked by comparison with those of a large number of airplanes the performance of which was known. Application of the formulas to specific examples will be made. The paper is printed in this issue of THE JOURNAL. Capt. George E. A. Hallett, of the engineering division of the Air Service, will outline the general procedure of designing and developing airplane engines followed by the organization that he heads at McCook Field. It is Captain Hallett's belief that many of these methods are applicable to the experimental development of motor-car and motor-truck engines to reduce the time needed for experimental tests and insure an earlier arrival at the stage where designs are perfected and ready for production. He will supplement the paper, which is printed on another page, with a description of the progress in airplane engineering that has been made by the Air Service Engineering Division in the past year. He will illustrate this talk with many interesting slides. An analogy by C. L. Egtvedt, printed in this issue of THE JOURNAL, will be read by title and discussed. At the conclusion of the discussion there will be an exhibition of authentic aviation pictures taken during the war with Germany. These films have been loaned by the Air Service and have been shown rarely in public. They possess great historical interest, as well as emphasize the airplane's military importance and the need of our keeping pace with foreign aeronautical development.

THE RESEARCH SESSION

The Research Session will be held Thursday morning, June 22. The major topic of discussion will be the desired volatility of motor gasoline. Papers will be given by W. S. James and C. T. Coleman, of the Bureau of Standards, and Dr. H. C. Dickinson, manager of the Research Department of the Society. Mr. James' paper will describe an instrument, developed by the Bureau of Standards, that photographically records the performance data of an engine when it is propelling a vehicle on the road under typical driving conditions. Acceleration, rated fuel-consumption, road and relative air-speeds, engine and transmission temperatures and other factors are all reproduced for later analysis. Mr. James will include in his presentation the conclusions drawn from extensive road-tests observed and studied with this ingenious instrument. One of the studies was made to determine the effect of decreased and increased gasoline volatility upon car performance and fuel economy. Practically all of Mr. James' work has been conducted on passenger cars. C. T. Coleman's paper, on the other hand, relates principally to the changes in performance and economy of motor trucks resulting from a lowering or raising of the end-point of the gasoline used. The tests to be described by Mr. Coleman are now being made by the Bureau of Standards, using the entire fleet of Post-Office transportation units in Pittsburgh and Philadelphia. Two different road conditions are represented in these cities; Philadelphia streets are smooth with few hills; Pittsburgh streets are rough with many hills. Four fuels of varying volatility are being employed in the tests, these ranging from aviation gasoline to a very heavy grade of gasoline. Fuel-consumption, oil dilution and oil consumption will be carefully observed and the resultant statistical data analyzed. Mr. Coleman will present the conclusions of this analysis in his paper at the Research Session.

Following these two papers, Dr. H. C. Dickinson will present the progress report of the Research Committee of the Society. He will give a complete and detailed description of the Society's Fuel Volatility Tests that are being conducted by the Bureau of Standards, Bureau of Mines and many of the motor-car companies under the direction of the Research Department of the Society. These tests are being financed by the American Petroleum Institute, the National Automobile Chamber of Commerce, and assistance is being given by the participating oil refiners and motor-car builders. The object of the tests is to determine what sort of petroleum fuel, as regards volatility, will give the average vehicle operator the most ton-miles of transportation per barrel of crude oil used in producing the fuel. Dr. Dickinson will call upon some of the chief engineers of motor-car companies participating in the tests for brief outlines of the procedure being followed in the work under their direction. It is only natural to anticipate the deepest interest in the Research Session. The knowledge gained in this one technical session should fully justify the expense of attending the Summer Meeting.

PASSENGER CAR SESSION

The technical session to be held Friday morning, June 23, has been designated as the Passenger Car Session. H. M. Crane will present his paper on A New System of Spring Suspension for Automotive Vehicles, which is printed in this issue of THE JOURNAL. He will discuss those factors influencing proper rear-axle spring suspension that have led him to design the rather unusual suspension described in the paper. It is the general belief among automobile critics that spring suspension and riding quality are features of present-day motor cars that warrant closer study on the part of the automotive engineer. For this reason it is hoped that Mr. Crane's paper will arouse an active discussion.

Engines with overhead camshafts and valves are becoming more popular in Europe and it is possible that a greater demand may be created for similar engines in this Country. P. M. Heldt's paper calls attention to the claims made for the overhead-camshaft engine and presents the mechanical features of a number of the popular European examples. The paper is printed in this issue of THE JOURNAL. The overhead-camshaft engine has been used in airplanes, motorboats and racing cars and has many advantages to recommend it in these instances. There is considerable difference of opinion, however, about its being the most practical type for the average operator of passenger cars. F. A. Bonham will read a paper presenting some pertinent suggestions on what the automotive engineer can do to assist the service and parts departments. Mr. Bonham has a number of constructive ideas that warrant attention and thorough discussion.

FUEL AND ENGINE SESSION

The Fuel and Engine Session on Saturday, June 24, will conclude the Summer Meeting. It will include four papers that contribute a large amount of valuable information for the engineer engaged particularly in the design of automotive powerplants. Thomas Midgley, Jr., will present the quantitative results of an analysis of the

Summer Meeting Program

TUESDAY, JUNE 20

10 a. m. and 2 p. m. — **STANDARDS SESSION**
- Standards Committee Reports and Discussion
- Papers on Standardization

2 p. m. — **TENNIS AND GOLF TOURNAMENTS START**

8 p. m. — **SEMI-ANNUAL BUSINESS MEETING**
- Address of President
- Reports of Committees and Officers
- Election of Nominating Committee Members

WEDNESDAY, JUNE 21

10 a. m. — **MOTORBUS SESSION**
- G. A. GREEN—The Design of the Motorbus
- R. E. PLIMPTON—Characteristics of Present-Day Motorbuses

10 a. m. — **AERONAUTIC SESSION**
- E. P. WARNER—Airplane Performance Formulas
- G. E. A. HALLETT—A Method of Developing Aircraft Engines
- C. L. EGTVEDT—Flighty Reflections
- Air Service Motion Pictures of the War with Germany

2 p. m. — Men's Golf Qualifying Round
Men's Tennis—Singles
Inter-Section Baseball

5 p. m. — Orchestra Concert

8 p. m. — **AQUATIC SPORT PROGRAM**

9:30 p. m. — Motion Pictures
Dancing

THURSDAY, JUNE 22

10 a. m. — **RESEARCH SESSION**
- H. C. DICKINSON—Report of the Activities of the Research Department of the Society.
  - Information Service
  - Fuel Research
  - Highway Research
- W. S. JAMES—Fuel Volatility Research at the Bureau of Standards, with Demonstration of Test Car Equipment.
- C. T. COLEMAN—Report of the Bureau of Standards Fuel Volatility Tests on Motor Trucks.
- Report of Chief Engineers of Companies Cooperating in Fuel Volatility Tests.

2 p. m. — **ANNUAL S. A. E. FIELD DAY**
- Track and Field Events
- Men's Golf Match Play
- Men's Tennis—Doubles and Singles

4 p. m. — Inter-Section Baseball

5 p. m. — Orchestra Concert

8 p. m. — Section Stunts

9:30 p. m. — Motion Pictures
Dancing

FRIDAY, JUNE 23

10 a. m. — **PASSENGER CAR SESSION**
- P. M. HELDT—Overhead Camshaft Passenger-Car Engines
- H. M. CRANE—New System of Spring Suspension for Automotive Vehicles
- F. A. BONHAM—The Automotive Engineer and the Service Problem

2 p. m. — **FINALS IN ALL SPORTS EVENTS AND TOURNAMENTS**

5 p. m. — Orchestra Concert

8 p. m. — **GRAND BALL**
Motion Pictures

9:30 p. m. — Dancing Contest
Presentation of Prizes

11 p. m. — Buffet Supper

SATURDAY, JUNE 24

10 a. m. — **FUEL AND ENGINE SESSION**
- F. C. MOCK and M. E. CHANDLER—The Hot-Spot Method of Heavy-Fuel Preparation.
- THOMAS MIDGLEY, JR., and T. A. BOYD—Detonation Characteristics of Some Blended Motor-Fuels.
- G. A. ROUND—Oil-Pumping
- A. A. BULL—Oil Consumption

Note: An appropriate program of entertainment, sports and cards will be conducted for the ladies each morning during the Technical Sessions.

Sports Events

Golf—Tuesday through Friday

Men's Championship Tournament
Men's Flag Consolation
Men's Driving Contest
Men's Putting Contest
Ladies' Championship Tournament
*Ladies' Putting Contest

Tennis—Tuesday through Friday

Men's Singles Tournament
Men's Doubles Tournament
*Ladies' Singles Tournament
Mixed Doubles Tournament

Track—Thursday Afternoon

*50-yd. Dash—Men under 30
50-yd. Dash—Men 30 to 40
50-yd. Dash—Men over 40
*50-yd. Dash—Boys under 12
*100-yd. Dash—Boys under 16
*50-yd. Dash—Ladies
*50-yd. Dash—Girls under 16
Fat Man's Race—Men weighing more than 3 lb. per in. of height
Three-Legged Race—Men
Potato Race—Men and Ladies
One-Legged Race—Hopping with legs tied

Field—Thursday Afternoon

Shot Put—Men
Hop, Step and Jump—Men
Standing Broad Jump—Men
*High Jump—Men
*Throwing Baseball—Ladies
*Egg Race—Ladies
Inter-Section Relay — Teams of four men

Baseball—Tuesday through Friday

For S.A.E. Section Championship Cup —Teams of nine—indoor or soft ball used

Trapshooting—Tuesday through Friday

For S.A.E. Section Champion Medal (Bring your own gun.)

Swimming—Wednesday Evening

33-yd. Swim—Men
33-yd. Swim—Ladies
*66-yd. Swim—Men
*66-yd. Swim—Ladies
Plunge for distance—Men
Plunge for distance—Ladies
*Fancy Diving—Men and Ladies
Inter-Section Relay — Teams of four men
Several Stunt Races

*Only these events open to guests

properties of blended motor-fuels. The data relate particularly to the comparative detonation values of the several fuels as determined by the bouncing-pin method. Mr. Midgley's paper appears in this issue of THE JOURNAL. Although much study has been made and many papers written on the subject of hot-spot manifolds, F. C. Mock and M. E. Chandler find a general misconception of the engineering fundamentals that must be followed in designing efficient manifolds of this type. Their paper collates many of the data now in existence and adds to them some pertinent information resulting from tests just completed by the authors.

One of the strongest and most persistent complaints received through the average service department is that of engines pumping oil. The trouble is aggravated by lowered fuel volatility, poor carburetion, and crankcase-oil dilution. Doubtless many of the members have spent much time and effort in seeking a means of preventing or alleviating this difficulty. Excessive carbon-deposit and fouled spark-plugs are the most common complaints chargeable to this cause. Appreciating the urgency of the problem, the Meetings Committee has secured two papers on the subject of Oil-Pumping which will be given at this Session. A. A. Bull has prepared a searching analysis of the causes of oil-pumping and excessive oil consumption in his paper. G. A. Round has approached the matter independently and from the lubricating engineer's viewpoint. Both of these papers are printed in this number of THE JOURNAL and are deserving of close study so that they may be thoroughly discussed at the time of their presentation at White Sulphur Springs.

Written Discussion of Papers

Eight of the papers to be read at the Summer Meeting are printed in this issue of THE JOURNAL. Preprints or abstracts of the other papers on the program will be sent to those who order them on the blank recently mailed to all members. Publication of the papers in advance of the meeting enables the members to study these important automotive engineering contributions with care. It provides an opportunity for the preparation of written discussion. Such written discussion need not be withheld until the time of the Summer Meeting. It should be forwarded to the Society offices where arrangements will be made for its presentation in the proper technical session. This suggestion applies particularly to those unable to attend the meeting and present their comments orally. It often happens that the information brought out in the discussion is of equal or greater value than that presented by the author in his paper. Read the Summer Meeting papers that touch upon matters in your field. If your experience is contradictory to that of an author, by all means submit it. If it supplements his opinions, strengthen his statements by contributing your own knowledge of the problem treated. Written discussion is a highly desirable addition to the papers, and members are strongly urged to mail such discussion to the Society offices in the case of the 1922 Summer Meeting papers.

Railroad Transportation

The reduced-fare privilege that has been secured from the railroads differs from the one in effect at the Annual Meeting last January. The members will receive a reduced-fare certificate about June 10. When transportation to White Sulphur Springs is purchased, this certificate entitles the member to a reduction of 25 per cent on the cost of a round-trip ticket. These certificates cannot be used by non-members, but they are valid for tickets purchased for dependent members of a Society member's

family. Round-trip tickets only may be purchased under this plan, no stop-overs are allowed and the same route must be used in both the trip to White Sulphur Springs and return. The Society has been fortunate in securing this reduced-fare concession from all of the railroad associations in the United States and the consequent saving to the members will be a substantial one. The rates from the principal automotive centers are shown in the accompanying table which is reprinted from the May issue of THE JOURNAL with one or two corrections.

Special Trains and Pullmans

Before making any Pullman reservations, get in touch with the Secretary of the Section nearest you and arrange to travel to the meeting in special cars with your fellow members. Two special trains have been scheduled to transport the Eastern and Western members to White Sulphur Springs. The Detroit, Cleveland and Midwest Sections have reserved special Pullman cars leaving their respective cities on Monday afternoon, June 19, and arriving in Cincinnati on the evening of the same day. Here they will be made-up into an S.A.E. Special all-Pullman train which will arrive in White Sulphur Springs, Tuesday morning, June 20, soon after breakfast. The members in northern Ohio can board the Cleveland cars; the members in Toledo and Michigan can be accommodated on the Detroit cars; the Indiana members should make reservations on the cars from Chicago.

The special train from the East will carry Pullmans from New York City and Philadelphia. New England and New York State members can make reservations on this train through the Society offices. The Eastern train leaves New York at 3:40 p. m., Eastern Time, on Monday afternoon, June 19, and arrives in White Sulphur Springs Tuesday morning before breakfast. Washington members can board this train, as it passes through their city.

The complete time-schedule of the special trains is given in the accompanying table, with the corresponding railroad fares. The Meetings Committee hopes to be able to announce soon the arrangement for similar special trains returning on Saturday, June 24, after the completion of the meeting. These trains will enable the members to remain at White Sulphur Springs until after lunch Saturday and still reach their home cities on Sunday morning, June 25.

It is very important that all members taking advantage of the special reduced-fares have their return-trip tickets validated by the railroad agent at White Sulphur Springs before boarding the return train. This portion of the fare-and-half ticket is not valid until the stamp of the White Sulphur Springs agent appears on it.

A Very Complete Sports Program

With the unusually complete sport facilities provided at White Sulphur Springs, it was to be expected that a

RAILROAD ACCOMMODATIONS TO WHITE SULPHUR SPRINGS, W. VA., FOR SUMMER MEETING
JUNE 20-24, 1922

		TIME SCHEDULE				RAILROAD FARES	
City	Railroad	Leave Monday, June 19	Arrive Cincinnati	S. A. E. Special Leaves Cincinnati	Arrive at White Sulphur Springs	Fare-and-Half Round-Trip	Tourist Round-Trip
Cincinnati	Chesap'ke & Ohio			9:45 p.m.	8:55 a.m.	$19.08	$20.62
Detroit	Big Four	11:45 a.m.	8:55 p.m.	9:45 p.m.	8:55 a.m.	28.08	31.97
Toledo	Big Four	1:35 p.m.	8:55 p.m.	9:45 p.m.	8:55 a.m.	24.98	28.22
Chicago	Big Four	1:00 p.m.	9:00 p.m.	9:45 p.m.	8:55 a.m.	34.47	38.70
Indianapolis	Big Four	6:15 p.m.	9:00 p.m.	9:45 p.m.	8:55 a.m.	25.01	27.75
Cleveland	Big Four	3:00 p.m.	9:35 p.m.	9:45 p.m.	8:55 a.m.	29.01	31.11
Dayton	Big Four	7:57 p.m.	9:35 p.m.	9:45 p.m.	8:55 a.m.	22.02	22.73

City	Railroad	Leave Monday, June 19	Arrive Washington	Leave Washington	Arrive at White Sulphur Springs	Fare-and-Half Round-Trip	Tourist Round-Trip
Boston	New Haven	8:00 a.m.	7:40 p.m.	10:15 p.m.	7:05 a.m.	$37.76	$49.04
Providence	New Haven	10:06 a.m.	7:40 p.m.	10:15 p.m.	7:05 a.m.	36.74	45.88
New Haven	New Haven	11:54 a.m.	7:40 p.m.	10:15 p.m.	7:05 a.m.	29.28	37.74
New York City	Pennsylvania	3:40 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	25.37	30.92
Manhattan Transf.	Pennsylvania	3:58 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	25.37	30.92
West Philadelphia	Pennsylvania	5:56 p.m.	9:25 p.m.	10:15 p.m.	7:05 a.m.	20.51	24.89
Baltimore	Pennsylvania	8:30 p.m.	9.25 p.m.	10:15 a.m.	7:05 a.m.	15.32	18.68
Buffalo	Pennsylvania	9:10 a.m.	8:50 p.m.	10:15 p.m.	7:05 a.m.	34.25	39.56
Washington	Chesap'ke & Ohio			10:15 p.m.	7:05 a.m.	13.16	17.28

very fine program of athletic diversions would be arranged. There will be much of the atmosphere of the intercollegiate meet in evidence at this Summer Meeting. Medals and cups are to take their place with the other handsome prizes of former years. Appropriate medals will be awarded to the golf, tennis and trapshooting champions. A prize goes to the member who proves himself to be the best all-round athlete. A cup will be contested for by the Section baseball teams. Most interesting of all, however, will be the struggle for the Section athletic championship. Predetermined point-scores have been assigned to the first, second and third places in all athletic events, including the baseball, golf and tennis tournaments. These scores will be credited to the Section represented by the victorious members or teams. When all sports events are concluded, the scores will be totaled and the championship cup awarded to the Section scoring the greatest number of points. In cases where a member is not affiliated with a Section, his points will be credited to the Section nearest him geographically as determined beforehand by the Sports Committee.

The golf tournament will be opened with a qualifying round, after which the contestants will be grouped into two or three flights based on their qualifying scores. The championship medal will be awarded to the winner in the first flight. The other flight winners will receive prizes in each case but these places will not contribute points to the Section Championship score.

The excellent tile swimming-pool at White Sulphur Springs enabled the Sports Committee to add a new feature to this year's program. On Wednesday evening a very fine aquatic program will be conducted. All may view the submarine dexterity of our more versatile members. The stunt races will be particularly amusing to the spectators and the sprinting and diving will create a fair amount of excitement.

The conduct of the sports program will be in the hands of a committee of which Mason P. Rumney is chairman. Mr. Rumney has announced the following as the personnel of his committee, each member being responsible for the branch of sports opposite his name.

SPORTS COMMITTEE

Mason P. Rumney, *Chairman*

Golf	Frank Lawrence
Tennis	Robert K. Floyd
Swimming	C. H. Brennan, C. B. Waterman
Baseball	Neil McMillan, Jr., E. R. Stroh
Field and Track	Lloyd P. Jones, E. V. Rippingille
Inter-Section Contest	Walter C. Keys
Clerk of Course	C. H. Van Sicklen
Professional Director	Victor Tomlinson

The complete list of sports events and tournaments is printed in another column. Entries should be made at the headquarters of the Sports Committee upon arrival at White Sulphur Springs.

GERMAN EXPORT TRADE

THERE is reason to believe that the advantage to the German export trade as a whole has been exaggerated. Certainly the available figures of aggregate German exports do not yet bear out the fear that Germany is making extraordinary progress in the world's markets. Moreover, as the German wage-earners and the general public have become more and more accustomed to think in terms of the external value of the mark, it appears that operating costs have tended to advance more nearly in proportion to advances in general prices. Again, the advantage obtained by the exporter who, for example, has been able to sell his goods for dollars and to buy marks at reduced external values, is in part offset by the price that he must pay for the imported raw materials necessary to the manufacture of goods for later exportation. In many other ways the apparent initial advantage is in part offset by corresponding disadvantages.

In specific lines of industry, however, there is no doubt that the German exporter has enjoyed great initial advantages. Manufacturers of other countries, in given cases, have actually faced cut-throat competition from Germany that for the time has seemed to threaten the existence of part of their foreign trade. Moreover, goods sold by Germany in the domestic markets of other nations have actually threatened to destroy the home market for some of the manufacturers of those nations.

While in the case of individual industries the German competition has been a real menace, the most important obstruction to normal trade recovery, so far as the German problem is concerned, is not to be found in the actual amount of destructive competition. On the contrary it is to be found in three other facts; the general uncertainty thrown into the entire trade situation by threatened, rather than actual, German competition; the danger, incurred in making contracts for future delivery, arising from the wide fluctuations of the exchanges, and the stimulation to, and often the necessity of, diverting money and energy from productive effort in normal lines to speculative or financial transactions in extraordinary lines.—*Commerce Monthly.*

STANDARDIZATION

STANDARDIZATION carried out on a sound engineering basis has the following significant aspects:

- It enables the buyer and the seller to speak the same language, and makes it possible to compel competitive sellers to do likewise
- Better quality of the product through ability of the manufacturer to concentrate on better design and through the reduction of manufacturing expense
- It lowers the unit cost to the public by making mass production possible
- By simplifying the carrying of stocks, it makes deliveries quicker and prices lower
- It decreases litigation and other factors tending to disorganize industry, the burden of which ultimately falls upon the public
- It eliminates indecision in both production and utilization, a prolific cause of inefficiency and waste
- It stabilizes production and employment, by broadening the possible market, and by making it safer for the manufacturer to accumulate stock during periods of slack orders to an extent that would not be safe with an unstandardized product
- By focusing on essentials, it decreases the selling expense, one of the serious problems of our economic system
- By concentrating on fewer lines, it enables more thought and energy to be put into designs, so that they will be more efficient and economical—Bulletin of the Chamber of Commerce of the United States.

Detonation Characteristics of Some Blended Motor-Fuels

By THOMAS MIDGLEY, JR.[1] AND T. A. BOYD[2]

SEMI-ANNUAL MEETING PAPER

Illustrated with CHARTS

THE effects of admixtures of various percentages of alcohol and alcohol-benzene mixtures for reducing the detonating tendency of paraffin hydrocarbons have been measured by the authors. These results represent an extension of previous work in which similar determinations were made for benzene and other aromatic hydrocarbons. The bouncing-pin apparatus was used for making the determinations. The data obtained by its use are considered to have a high degree of accuracy.

In order that the effects of the blending materials might be measured through as wide a range as practicable, they were blended with kerosene for making the majority of the determinations. This made it possible to ascertain the characteristics of the materials up to a concentration of 80 per cent of benzene or 50 per cent of alcohol without introducing the difficulties due to excessively high engine compression. Because xylidine has the property of exerting a powerful suppressing action on detonation when present in a fuel in percentages that are relatively very small, the standard used as a basis of comparison in the tests was composed of small percentages of xylidine in the paraffin fuel. Tables and curves are appended that show the results of the tests in detail.

THAT the addition of benzene and other aromatic hydrocarbons to paraffin-base gasolines greatly reduces the tendency of these fuels to detonate when used in automobile engines has been known for some time. Also, it is well known that alcohol when blended with a paraffin-base gasoline improves the combustion characteristics of the fuel. The extension of the by-product coking industry in the United States during recent years has resulted in such an increase in the production of light oil that it can be absorbed only by the use of a part of the material as a motor fuel. This, coupled with the freedom from detonation that characterizes the combustion of benzol in engines, is causing the use of benzol-gasoline blends as motor fuels to be extended as rapidly as the benzol that is available will permit. The scarcity and high price of gasoline in countries where sugar is produced and the abundance of raw material for making alcohol there have resulted in a rather extensive use of alcohol for motor fuel in these districts. As the reserves of petroleum in this Country become more and more depleted the use of benzol, and particularly of alcohol, in commercial motor-fuels will probably become greatly extended.

Alcohol as produced commercially dissolves in gasoline only to a very small extent; but the addition of a proper percentage of an aromatic hydrocarbon, such as benzol, toluol or xylol, to the mixture renders the ingredients completely miscible. The availability of benzol for blending with motor fuels makes possible the use of alcohol in such mixtures. Blended motor-fuels containing the three ingredients, alcohol, benzol and gasoline have been sold in some parts of this Country for some time.

The object of this paper is to report the progress that has been made in measuring the detonating tendencies of mixtures of some of the principal materials that are used as components of the blended motor-fuels now available commercially. The detonation characteristics of aromatic hydrocarbons have been presented in a paper entitled Detonation Characteristics of Blends of Aromatic and Paraffin Hydrocarbons that is soon to be published in the *Journal of Industrial and Engineering Chemistry*. These results have since been extended by determining the detonation characteristics of blends of alcohol and of alcohol-benzol mixtures with paraffin hydrocarbons. Although these data are incomplete and have not been obtained in such a form as to be universally usable, it was thought advisable to present some of them in this way, especially in view of the fact that a considerable amount of the matter dealing with this subject that has been published in the past is in error. As examples of this the following statements by Ricardo may be cited:

(1) Xylene is inferior to toluene for the suppression of detonation[3]

(2) The detonation point of mixtures of ethyl alcohol, acetone, toluene and xylene with paraffin and other hydrocarbons, follows a straight law when the mixture is apportioned by weight and not by volume; that is, the addition of 40 per cent by weight of, say, toluene to hexane would raise the detonation point exactly four times as much as the addition of 10 per cent[4]

The primary reason for the unreliability of some of the data on blending characteristics that have been obtained and published is the previous lack of a means for measuring the detonating tendencies of fuels with sufficient accuracy. The use of the bouncing-pin method for the measurement of the intensity of detonation, however, gives results that are reliable and have a high degree of accuracy. This instrumentation, which is illustrated in Fig. 1 and was described in our paper entitled Methods of Measuring Detonation in Engines[5] that was presented at the 1922 Annual Meeting of the Society, has made it possible to secure the data that are presented in this paper.

In order that the effects of blending materials might be measured in as wide a range of concentrations as practicable, they were blended with kerosene for making the majority of the determinations reported in this paper. The greater tendency of kerosene than lighter paraffin hydrocarbons to detonate made it possible to determine

[1] M.S.A.E.—Chief of the fuel section, General Motors Research Corporation, Dayton, Ohio.

[2] Assistant chief of the fuel section, General Motors Research Corporation, Dayton, Ohio.

[3] See *Automobile Engineer* (London) March, 1921, p. 96; also THE JOURNAL, May, 1922, p. 311.

[4] See *Automobile Engineer* (London) March, 1921, p. 94.

[5] See THE JOURNAL, January, 1922, p. 7.

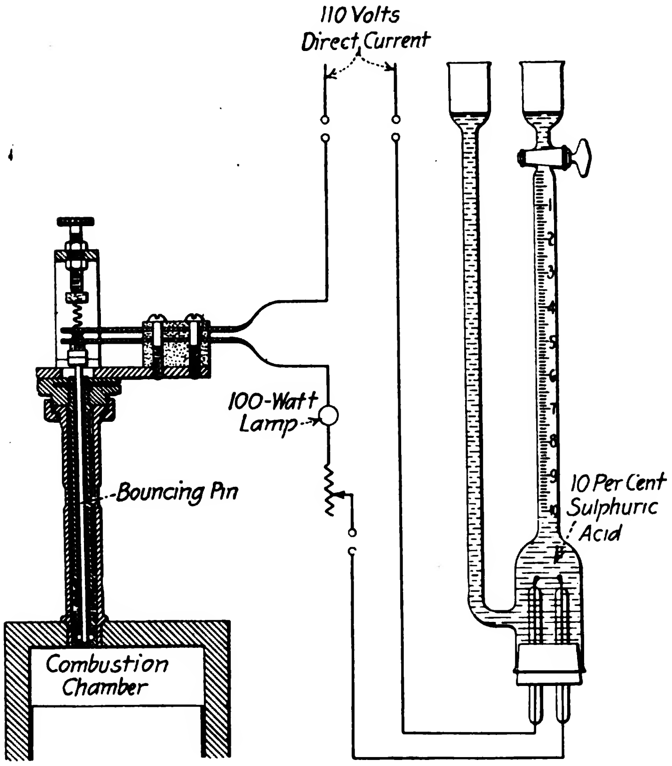


FIG. 1—ARRANGEMENT OF APPARATUS FOR MEASURING DETONATION BY THE BOUNCING-PIN METHOD

the detonation characteristics of blends up to a concentration of 80 per cent benzene or 50 per cent alcohol without introducing the difficulties incident to excessively high engine compression. The curves of Fig. 2 show that in general the characteristics of gasoline blends follow closely those of kerosene. This agreement is still better on the molecular basis, as is brought out in the previously mentioned paper on Detonation Characteristics of Blends of Aromatic and Paraffin Hydrocarbons. So that results obtained from a given concentration of blending material in kerosene are applicable within fairly close limits to blends of similar compositions in which the kerosene has been replaced by a gasoline.

On account of variations in engine conditions it is evident that data obtained from any particular engine are applicable in a quantitative way only to that one design and set of conditions. But, although widely different behavior may characterize the combustion of a certain fuel in two different engines, the relative behaviors of two given fuels will be comparative in whatever type of engine they may be run. Hence, in measuring the detonating tendency of any fuel it is essential that some standard be used as a basis of comparison. In the tests reported herein small percentages of xylidine in the same paraffin fuel that was used for blending with the alcohol and with the aromatic hydrocarbons were employed as a standard. Xylidine has the property, common to aromatic amines and considerably more marked in a number of other materials, of exerting a powerful suppressing action on detonation, when present in a fuel in percentages that are relatively very small. Thus, it may be seen from Fig. 2 that 1 per cent of xylidine in kerosene is equivalent for the elimination of detonation to about 15 per cent of benzene in the same material. This property of xylidine makes it possible to convert kerosene into a fuel that will withstand very high compressions without knocking, and with the addition of such a small percentage of xylidine that the combustion characteristics of the kerosene, other than its tendency to detonate, are not materially changed.

PROPERTIES OF MATERIALS USED AS FUELS

The materials used as ingredients of the various fuels that were either examined or employed as standards in the examinations, the results of which are reported in this paper and in the previous one referred to above, were "high-test" gasoline, commercial gasoline, kerosene, xylidine, benzene, or 90-deg. benzol, toluene, xylene and alcohol. The xylidine employed was a commercial material composed of the mixed xylidines. The alcohol used was absolute ethyl. The use of absolute rather than commercial denatured alcohol in these tests was necessary on account of the almost complete insolubility of the latter in paraffin oils, unless a "binder" such as benzol is used. Some physical properties of the other materials included in this list are presented in Table 1.

A ¾-kw. Delco-Light engine was used for making all the determinations. This is a single-cylinder, air-cooled engine, direct-connected to a 32-volt, direct-current generator, and having a 2½-in. bore and a 5-in. stroke. The engine was standard, except that a means was provided for adjusting the spark-timing, and that the compression was increased by stages from the normal ratio of 3.47 to 1 to a ratio of 5.36 to 1. This was done by a series of cylinder-heads that had been cut down by different amounts, so as to reduce the clearance volume by corresponding stages. The device employed for measuring the relative intensities of different detonations and called the bouncing-pin apparatus is shown diagrammatically in Fig. 1.

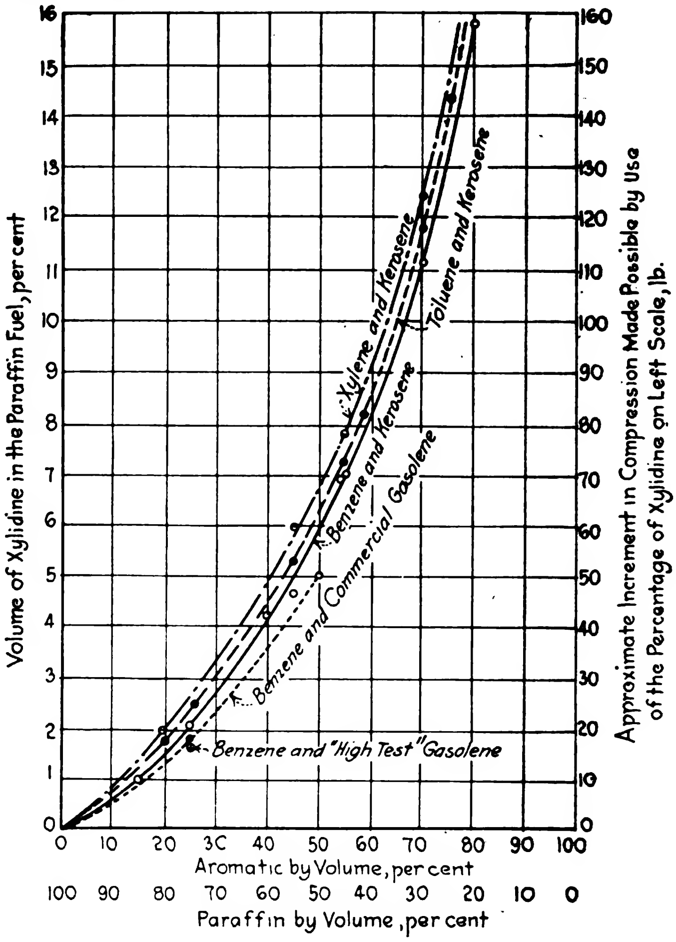


FIG. 2—GRAPHICAL ARRANGEMENT OF THE DATA OBTAINED IN DETERMINING THE DETONATION CHARACTERISTICS OF BLENDS OF AROMATIC AND PARAFFIN HYDROCARBONS

The method used in making the determinations can best be explained by giving a specific example, for which the comparison of a blend containing 45 per cent of benzene and 55 per cent of kerosene with fuels composed of small percentages of xylidine in kerosene was employed. A compression-ratio of 3.87 to 1 was used, so that some detonation would occur, but which was not so violent as to cut down the power of the engine seriously or to cause it to operate in an erratic manner. The fuel under examination was put into one side of the fuel system and the mixing-valve on the engine was adjusted so as to give a maximum of detonation. This adjustment produces close to the leanest possible mixture for maximum power. By trial it was found that 5 per cent of xylidine in kerosene had a slightly less detonating tendency than the benzene-kerosene blend under examination. This fuel was then placed in the other side of the fuel system and its level was adjusted so as to give the point of maximum detonation. The setting of the mixing-valve was left undisturbed throughout the determination so that the compression pressure of the engine would be unchanged. A number of alternate 1-min. runs were then made, with the 5-per cent-xylidine-in-kerosene and the benzene-kerosene blend. The amount of gas evolved in the electrolytic cell during each period was recorded. The output of the generator in volts and amperes was also kept as a matter of record. After three to six runs had been made with each fuel, the benzene-kerosene blend was replaced with 4 per cent of xylidine in kerosene and a second series of runs was made in the same manner. The amounts of gas evolved during the 1-min. runs were then averaged, and the values thus obtained for the xylidine-kerosene fuels were plotted on a coordinate chart having as its vertical axis the amount of gas evolved per minute and as its horizontal axis the percentage of xylidine in kerosene. These two points were next joined by a straight line. From the point at which this line crossed the horizontal line corresponding to the volume of gas evolved by the benzene-kerosene fuel under examination a vertical projection was made to the horizontal scale at the bottom of the chart giving the percentage of xylidine in kerosene. The intersection of this projected line with the bottom scale then gave directly the percentage of xylidine in kerosene that was equivalent in its effect for the supression of detonation to 45 per cent of benzene in kerosene.

Results

The data obtained in the tests on which this paper is based are given in Tables 2 and 3. The averages of the results given in these tables have been used in plotting the curves on the chart reproduced in Fig. 3. Attention is called to the consistency of the data, and to the agreement between the results obtained with like concentrations of given materials. The close checks that were made in different determinations of the detonation characteristics of a given blend indicate that the values as obtained have a high degree of accuracy.

Fig. 2 gives a graphical presentation of the results obtained in measuring the detonation characteristics of blends of aromatic and paraffin hydrocarbons. These data are tabulated and discussed in the previous paper referred to above. From Fig. 2 the rapidly increasing slope of the curves as the percentage of the aromatic constituent is raised may be noted. Thus the curves show that the presence of only a small percentage of an

TABLE 1—PHYSICAL DATA ON THE FUELS USED IN THE TESTS

Hydrocarbon	Kerosene	Commercial Gasoline	"High-Test" Gasoline	Benzene, 90-Deg. Benzol	Toluene	Xylene
Specific Gravity at 15 Deg. Cent. (59 Deg. Fahr.)	0.816	0.734	0.704	0.878	0.860[a]	0.860[a]
Absorption in Cold Sulphuric Acid, per cent	7	5	3	....	....	....
Distillation Temperatures						
First Drop, deg. cent.	186.0	40.0	44.0	74.0	107.0	135.0
deg. fahr.	366.8	104.0	111.2	165.2	224.6	275.0
10 Per Cent, deg. cent.	201.0	65.0	59.0	77.5	108.0	136.0
deg. fahr.	393.8	149.0	138.2	171.5	226.4	276.8
20 Per Cent, deg. cent.	207.0	83.5	68.5	78.7	108.5	136.2
deg. fahr.	404.6	182.3	155.3	173.7	227.3	277.2
30 Per Cent, deg. cent.	212.0	99.0	76.0	79.2	108.6	136.5
deg. fahr.	413.6	210.2	168.8	174.6	227.5	277.7
40 Per Cent, deg. cent.	217.5	111.5	82.7	79.8	108.7	136.7
deg. fahr.	423.5	232.7	180.9	175.6	227.7	278.1
50 Per Cent, deg. cent.	222.0	125.0	89.3	80.1	108.8	136.9
deg. fahr.	431.6	257.0	192.7	176.2	227.8	278.4
60 Per Cent, deg. cent.	227.5	140.0	96.0	80.5	108.8	137.1
deg. fahr.	441.5	284.0	204.8	176.9	227.8	278.8
70 Per Cent, deg. cent.	233.5	157.5	103.0	81.1	108.8	137.3
deg. fahr.	452.3	315.5	217.4	178.0	227.8	279.1
80 Per Cent, deg. cent.	241.0	177.0	114.0	82.0	108.9	137.5
deg. fahr.	465.8	350.6	237.2	179.6	228.0	279.5
90 Per Cent, deg. cent.	253.5	200.0	128.0	85.0	109.0	137.8
deg. fahr.	488.3	392.0	262.4	185.0	228.2	280.0
95 Per Cent, deg. cent.	268.0	219.0	157.0	92.5	109.2	138.1
deg. fahr.	514.4	426.2	314.6	198.5	228.6	280.6
Dry, deg. cent.	291.0	226.0	178.0	....	....	....
deg. fahr.	555.8	438.8	352.4	....	....	....

[a]Approximate.

TABLE 2—DATA OBTAINED IN DETERMINING THE DETONATION CHARACTERISTICS OF VARIOUS BLENDS OF ALCOHOL AND KEROSENE

Determination Number	Compression-Ratio	Spark, Degrees Before Top Dead-Center	Alcohol-Kerosene Blend: Alcohol by Volume, per cent	Alcohol-Kerosene Blend: Kerosene by Volume, per cent	Determined Equivalent Xylidine in Kerosene by Volume, per cent: Individual	Determined Equivalent Xylidine in Kerosene by Volume, per cent: Average
74	3.47 to 1	43	15	85	2.25	
75	3.47 to 1	43	15	85	2.30	
76	3.47 to 1	43	15	85	2.40	2.30
68	3.87 to 1	32	25	75	4.60	
69	3.87 to 1	32	25	75	4.60	
70	3.87 to 1	32	25	75	4.60	4.60
53	4.59 to 1	32	35	65	7.40	
54	4.59 to 1	32	35	65	7.15	
55	4.59 to 1	32	35	65	7.00	
56	4.59 to 1	32	35	65	7.10	7.20
50	5.36 to 1	25	50	50	12.40	
51	5.36 to 1	25	50	50	12.70	
52	5.36 to 1	25	50	50	12.80	12.60

TABLE 3—DATA OBTAINED IN DETERMINING THE DETONATION CHARACTERISTICS OF VARIOUS BLENDS OF AN EQUI-MOLECULAR MIXTURE OF ALCOHOL AND BENZENE WITH KEROSENE

Determination Number	Compression-Ratio	Spark, Degrees Before Top Dead-Center	Fuel Blend: Equi-molecular Alcohol and Benzene, by Volume, per cent	Fuel Blend: Kerosene, by Volume, per cent	Determined Equivalent Xylidine in Kerosene, by Volume, per cent, Individual	Average
77	3.47 to 1	43	20	80	2.35	
78	3.47 to 1	43	20	80	2.25	
79	3.47 to 1	43	20	80	2.15	2.25
71	3.87 to 1	32	35	65	4.65	
72	3.87 to 1	32	35	65	4.75	
73	3.87 to 1	32	35	65	4.75	4.75
80	4.59 to 1	32	50	50	8.60	
81	4.59 to 1	32	50	50	8.20	
82	4.59 to 1	32	50	50	8.60	8.50
84	5.36 to 1	25	65	35	13.15	
86	5.36 to 1	25	65	35	13.55	
87	5.36 to 1	25	65	35	13.45	
88	5.36 to 1	25	65	35	13.30	13.40

aromatic hydrocarbon in a paraffin fuel has but a slight effect toward supressing detonation. This is in agreement with the practical observation made by those who have used benzol-gasoline blends that the addition of less than 20 per cent of benzol to a commercial gasoline or a naphtha exerts only a small influence toward causing the engine to give smoother operation. But when benzol is blended with paraffin fuels in larger percentages its effect increases rapidly as its concentration relative to the paraffin fuel is raised. This is due, in part at least, to the greater percentage of reduction in the amount of the paraffin constituent present as the aromatic content of the blend is increased. It will also be observed from Fig. 2 that toluene on the basis of volume is more effective than benzene for eliminating detonation conditions, and that xylene is, in turn, still more effective than toluene for this purpose.

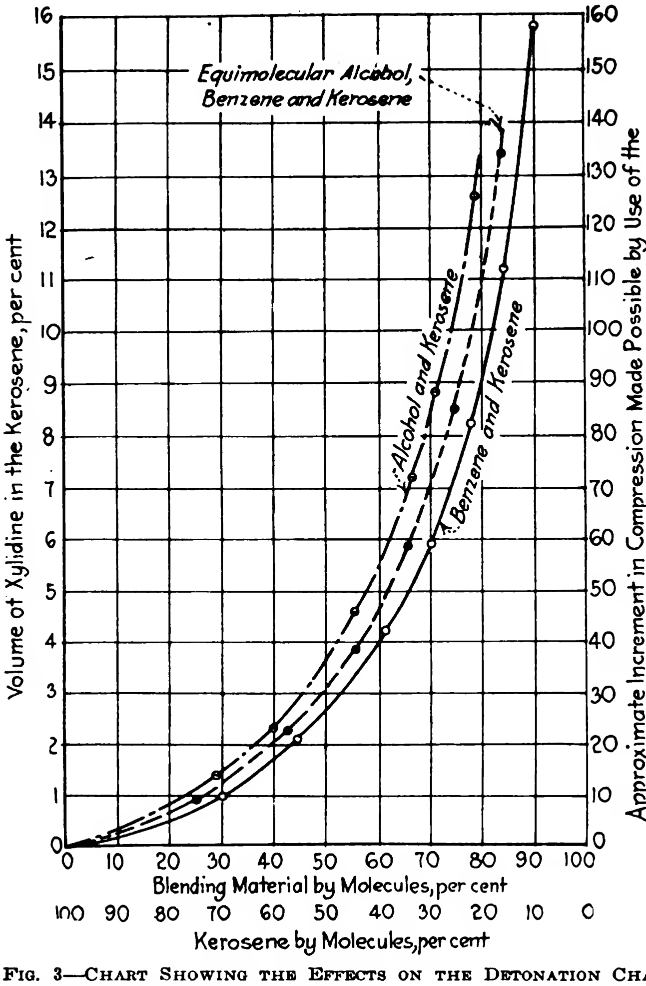


FIG. 3—CHART SHOWING THE EFFECTS ON THE DETONATION CHARACTERISTICS OF KEROSENE OF BLENDING WITH IT VARIOUS PERCENTAGES OF ALCOHOL AND BENZENE

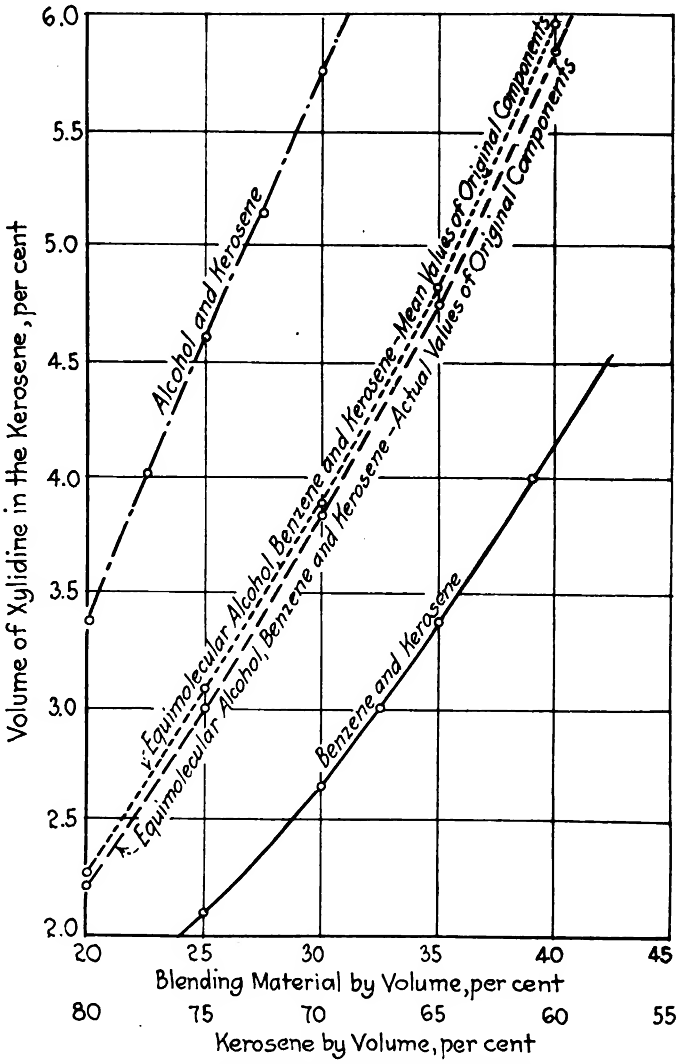


FIG. 4—A BLEND OF TWO FUELS SOMETIMES HAS A GREATER TENDENCY TO DETONATE THAN IS INDICATED BY A MEAN OF THE VALUES OF ITS COMPONENTS

The vertical scale at the right of Fig. 2 shows approximately the increments in compression pressure of the engine that are made possible by the addition to a paraffin fuel of the corresponding percentages of xylidine given on the vertical scales to the left. From the two scales on the charts it will be observed that the addition of 1 per cent of xylidine to a fuel that gives incipient detonation in a certain engine makes it possible to raise the compression of the engine about 10 lb., without any greater detonation being obtained than with the untreated fuel at the original and lower compression. The increment in compression made possible by each per cent of xylidine added to the fuel can only be approximated, but the values given are based upon a number of observations made under practical operating conditions, on engines ranging from the single-cylinder Delco-Light to the 12-cylinder Liberty, over a compression range of from 50 to 160 lb. By referring the curves given on the charts to the scales at the right, an approximation may be obtained of the relative composition necessary to give smooth operation at a corresponding increase above the normal limiting or critical compression of the paraffin fuel alone.

TABLE 4—A COMPILATION OF DATA BASED ON FIG. 3 AND ILLUSTRATING THE OBSERVATION THAT A BLEND OF TWO FUELS SOMETIMES HAS A GREATER TENDENCY TO DETONATE THAN IS INDICATED BY THE CHARACTERISTICS OF ITS COMPONENTS

(1) Blending Material in Fuel on the Basis of Volume, per cent	20	30	40	50
(2) Excess Effect of Alcohol over Benzene in Equivalent Percentage of Xylidine	1.900	3.050	4.650	6.650
Excess Effect of Alcohol-Benzene Mixture over Benzene in Equivalent Percentage of Xylidine				
(3) Actual Value	0.700	1.150	1.700	2.550
(4) Mean Value of Components	0.750	1.200	1.820	2.600
(5) Ratio of Value in Item 2 to That in Item 3	0.369	0.377	0.366	0.384

The data in Tables 2 and 3, together with the benzene-kerosene curve of Fig. 2, are arranged graphically in Fig. 3. This chart shows to a good advantage the relation between the effectiveness of alcohol and that of benzol for the suppression of detonation when blended with a paraffin fuel. It will be observed that on the volume basis alcohol is considerably more effective than benzol for this purpose. Thus, from the chart, 35 per cent of alcohol blended with kerosene produces an effect in suppressing the detonating tendency of the fuel equal to that given by 55 per cent of benzol blended with the same material.

The middle curve of Fig. 3 is plotted from data obtained in determining the effect of blending an equi-molecular mixture of alcohol and benzene with kerosene in the percentages by volume as indicated in Table 3. This equi-molecular mixture was composed of 39.2 per cent of alcohol and 60.8 per cent of benzene by volume. A given volume of the alcohol-benzene mixture contained, of course, equal amounts of alcohol and benzene on the molecular basis. Thus, 100 cc. of the mixture contained 0.675 gram molecules of each of the ingredients, alcohol and benzene. The curve of the detonation characteristics of the fuel obtained by blending this mixture with kerosene should lie somewhere between the curves obtained in a similar way when using alcohol-kerosene and benzene-kerosene blends, respectively. Since the alcohol-benzene mixture contained 39.2 per cent of alcohol and 60.8 per cent of benzene by volume, it is natural to suppose that for a given concentration of this mixture in kerosene the point representing the detonation value of the blend should lie above the benzene-kerosene curve a distance equal to 0.392 part of the differential between similar points on the benzene-kerosene and the alcohol-kerosene curves. Because they are of such small magnitude no account has been taken here of the changes in volume that occur when some of these materials are blended. In making the mixtures used in the tests, each ingredient was measured separately; that is, before being blended. But, while the actual points lie very close to this mean value, it is significant that in every case they are below it. This statement is illustrated by the curves of Fig. 4 and by the data presented in Table 4. The values given in the first three items of Table 4 were taken directly from the curves of Fig. 3, and those in Item 4 were obtained by multiplying the corresponding values in Item 2 by 0.392. The curves in Fig. 4 are based on those in Fig. 3 and on the figures in Table 4.

TABLE 5—RELATIONS BETWEEN AMOUNTS OF XYLIDINE AND ALCOHOL REQUIRED TO IMPART TO KEROSENE LIKE COMBUSTION CHARACTERISTICS FROM THE STANDPOINT OF DETONATION

Xylidine in Kerosene, by Volume, per cent	In Percentages, by Volume, Alcohol	Kerosene	In Equivalent Percentages, by Molecules, Alcohol	Kerosene
1.4	10.0	90.0	29.0	71.0
2.3	15.0	85.0	40.0	60.0
4.6	25.0	75.0	55.7	44.3
7.2	35.0	65.0	67.0	37.0
8.8	40.0	60.0	71.5	28.5
12.6	50.0	50.0	79.0	21.0

It appears, then, that the mixture obtained by blending two fuels of definite detonation characteristics sometimes has a greater detonating tendency than is indicated by the arithmetical mean between the components on the basis of the percentage in which each is present. Attention has previously been called to the fact that in some cases two fuels of similar detonation characteristics, upon being blended, give a fuel that has a very much greater tendency to detonate than either of the ingredients.[6] The results obtained in the tests reported in this paper appear to indicate that this characteristic is common to blended fuels; that is, the detonating tendency of a fuel composed of two ingredients is greater than the average of the values representing the detonating tendencies of the two components taken separately. But this is a point that has not yet been determined accurately for a wide range of different materials.

TABLE 6—RELATIONS BETWEEN AMOUNTS OF XYLIDINE AND EQUI-MOLECULAR MIXTURES OF ALCOHOL AND BENZENE REQUIRED TO IMPART TO KEROSENE LIKE COMBUSTION CHARACTERISTICS FROM THE STANDPOINT OF DETONATION

Xylidine in Kerosene, by Volume, per cent	In Percentages, by Volume, Alcohol-Benzene	Kerosene	In Equivalent Percentages, by Molecules, Alcohol-Benzene	Kerosene
0.95	10.0	90.0	24.7	75.3
2.25	20.0	80.0	42.5	57.5
3.85	30.0	70.0	56.0	44.0
5.85	40.0	60.0	66.3	33.7
8.50	50.0	50.0	74.7	25.3
13.40	65.0	35.0	84.5	15.5

[6] See THE JOURNAL, January, 1922, p. 10.

In Tables 5 and 6 and in Fig. 5 are shown the results obtained by converting the percentages of the fuel ingredients by volume to the molecular basis. The compositions in percentages by volume as given in Tables 5 and 6 were taken from the curves in Fig. 3. In computing the percentage composition of a blend on the molecular basis from its composition by volume the specific gravity and the molecular weight of each of the ingredients were employed. In view of the somewhat wide distillation-range of the benzol used in the tests, the values for which are given in Table 1, a molecular weight of 79 instead of 78 was taken for the benzene. Since kerosene is not a definite compound, and therefore does not have a definite molecular weight, it was necessary to compute an "average molecular weight" for the material. This was done by the method of Wilson and Barnard.[7] For this purpose the distillation data of the fuel given in Table 1 were arranged in the usual type of curve in which the temperature is plotted on the vertical axis against the percentage distilled on the horizontal axis. From this curve the percentages of the fuel distilling in each 10-deg. interval were obtained, and these values were plotted on a chart in which the scale of the vertical axis was in terms of temperature. The average boiling-point of the fuel was taken as the point at which a perpendicular passed through the center of gravity of the area enclosed under this differential distillation-curve cut the horizontal or temperature axis. As determined in this way the average boiling-point of the kerosene used in these tests was 226 deg. cent. (439 deg. fahr.). The approximate molecular weight of the kerosene was computed so as to bear the same proportionate relation to the hydrocarbons next above and below it in the paraffin series as the average boiling-point of the fuel bore to the normal paraffin hydrocarbons occupying like positions with respect to it, dodecane and tridecane. Obtained in this way, which it is recognized gives only a close approximation, the average molecular weight of the kerosene was 178.5.

[7] See THE JOURNAL, November, 1921, p. 313.

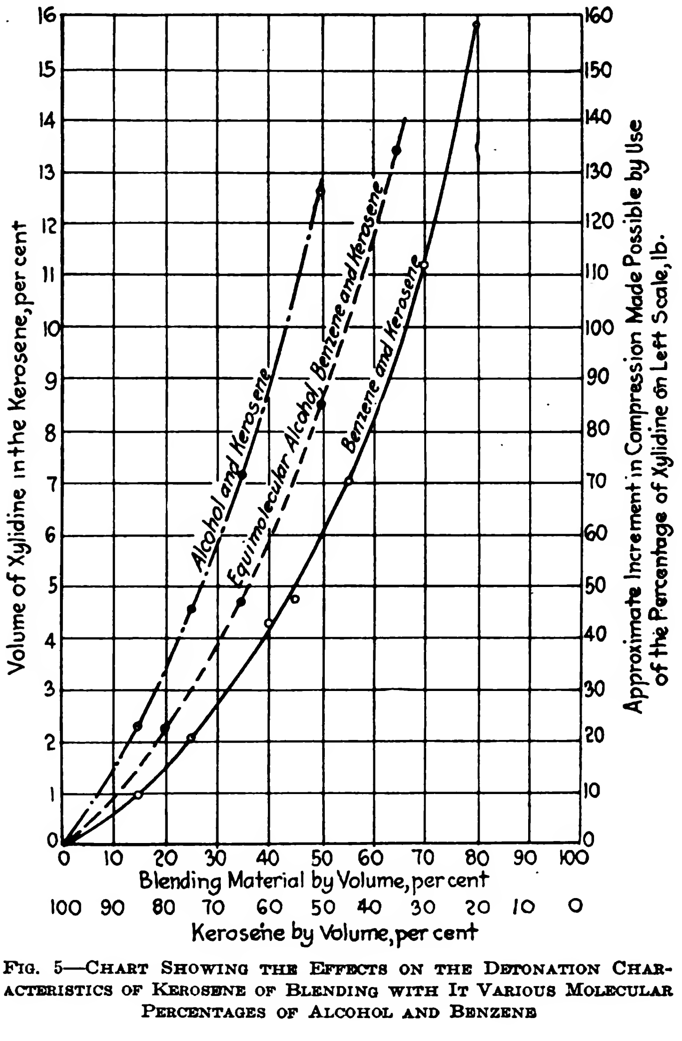


FIG. 5—CHART SHOWING THE EFFECTS ON THE DETONATION CHARACTERISTICS OF KEROSENE OF BLENDING WITH IT VARIOUS MOLECULAR PERCENTAGES OF ALCOHOL AND BENZENE

On the molecular basis there is not such a marked difference between the effectiveness of alcohol and that of benzol for suppressing detonation as shown in Fig. 5 as there is on the volume basis as indicated in Fig. 3. The closer agreement between the effects of the two materials on the basis of molecular concentration is due to the smaller size of the alcohol molecule as compared with that of the benzene molecule. But even on this basis alcohol is still more effective than benzene for suppressing detonation. Thirty-five per cent of alcohol, which, as is indicated above, is equivalent in effect to 55 per cent of benzene on the volume basis, is equivalent to 42 per cent of benzene on the molecular basis.

Since the middle curve in Fig. 5 is based on the results obtained by blending an equi-molecular mixture of alcohol and benzene with kerosene, it is natural to suppose that any point on it should lie half-way between the points occupying like positions on the two outside curves, which were obtained by blending alcohol and benzene separately with kerosene. However, the points on the middle curve do not occupy this middle position; but, as is the case on the volume basis, as shown in Table 4 and Fig. 4, they are uniformly lower than the mean values of the original components, thus showing that in this case a blend of the two ingredients is not so effective for the suppression of detonation as the mean average of the effects of the ingredients would indicate.

THE FARMER'S REWARD

IT is not at all certain that the farmers are rewarded less than the rest of us. In the height of the war period he seems to have done better than the mass of the rest of us; it has been shown that in 1918 the average reward per farmer for labor, risk and management, measured by the prices of 1913, was $826; of factory employes, $725, and of Government employes, $566.

Before the war the farmer was low man in the scale, and he may have returned there, but it is not clear whether he has been properly debited with the value of what he consumes from the product of his farm, including fuel. Taking that into account and also the entirely legitimate differences in the character of clothing and other necessities required, respectively, by urban and rural dwellers, as well as in dwelling site values, ground rent of homes, the farming group may not seem so badly treated as some people might think after all.

This does not militate in the least against the desirability of absolutely fair and just treatment of the farmer, together with such governmental consideration as may not be special privilege rather than primarily for the common gain of all concerned.—Robert Luce in *Economic World.*

A Method of Developing Aircraft Engines

By Capt. George E. A. Hallett, U. S. A.[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs

THE general method of procedure taken by the Air Service before beginning the actual design and construction of the necessary types of aircraft engine is outlined and the four steps of the development subsequent to a very complete study of existing domestic and foreign engines are stated.

After checking over the layouts, if all the details are agreed upon by both the designer and the Engineering Division, the contract is placed, usually for two experimental engines, and the construction work is begun.

Acceptance tests are made to demonstrate that the engine is capable of running at normal speed and firing on all cylinders. These are followed by the standard performance test made on the dynamometer at McCook Field. The results of the latter test determine whether the engine can enter the 50-hr. endurance test. The engine is then torn-down and inspected for wear. Suggested modifications are embodied in reconstructed engines which eventually fulfill the requirements. Descriptions of the various tests are given and commented upon.

THE development of an aircraft engine is defined as the work which is done between the time of making the initial scale layout and the time when the engine is ready for production. The purpose of this paper is to describe briefly the method pursued by the Engineering Division at McCook Field in accomplishing this work. Before entering into a description of the methods of aircraft engine development the need for the many types will be explained briefly and what are the general steps to be taken before beginning the actual design and construction of these types.

At the close of the war, very few fully developed types of engine were available to our Air Service. We had a bombing engine which was good for various two-seater airplanes, but we did not have entirely satisfactory pursuit, training or heavy-bombing engines. The operations group of the Air Service promptly prepared a set of performance specifications for 16 types of aircraft for as many military uses. Working from these specifications, a similar list was prepared of the sizes and types of engine that would be needed in this program, with the idea of making them available as rapidly as possible; and a very complete study of existing domestic and foreign engines was begun. First, standard test methods were laid down. Next, standard test-report outlines and contents were decided upon. Then domestic and foreign engines were tested in two ways, (*a*) by a so-called standard test that included thorough and accurate measurements of all phases of the engine's performance and in some cases, (*b*) by a 50-hr. test for the purpose of comparing the durability of the engine with that of others. As this work got well under way, we started to work out improvements for existing domestic types and arranged with suitable contractors for the design and construction of new types that appeared to be needed. In a very few cases where no contractors could be interested the designs were laid down at McCook Field.

The study of existing domestic and foreign engines provided valuable data on such characteristics as brake mean effective pressure, horsepower per cubic inch piston displacement, pounds of engine per cubic inch of displacement, comparative freedom from vibration of different types and comparative durability. It was noted that the fuel-consumption was controlled largely by the compression-ratio, the type of carbureter and the type of manifold, provided the engine showed reasonable mechanical efficiency and brake mean effective pressure. These data on the characteristics of the best existing engines served as a fairly good guide in regard to what types of design and construction would prove most satisfactory for incorporation in the engines to be developed, and it should be noted particularly that since all these measurements were taken on the same standard equipment and by the same standard methods, the results were unusually comparable.

Development Procedure

In general, the steps in the development of engine types have been as follows:

(1) The design and layout are started in most cases by civilian contractors
(2) The Engineering Division, upon receipt of these layouts, generally checks the stress and weight calculations
(3) The engine is checked from a standardization and installation point of view; in other words, the gasoline, oil, water, throttle and electrical connections must be standard and located at points that will be accessible after the engine has been installed; provision must be made for mounting the standard electric starter, gun synchronizers, gasoline pump, tachometer drive and electric generator. Much serious trouble in airplane design and engine maintenance is thus avoided
(4) The layout is checked to see that it has embodied the latest experience of the Engineering Division and its contractors in design and constructional details

The Engineering Division acts as a clearing-house for approved practice in design and construction. For example, the good points of an engine designed by the Engineering Division or a civilian company can be applied to an engine designed by some other company. This practice has been of great benefit when engines have been designed by the various civilian contractors as well as when designed by the Engineering Division.

After checking the layouts and when all the details have been settled to the satisfaction of the designer and the Engineering Division, the experimental contract is placed and the construction work started. The contract

[1] S.M.S.A.E.—Chief of powerplant section, engineering division, Air Service, Dayton, Ohio.

Fig. 1—Typical Set of Crankshaft Gears That Have Been Damaged by Whipping of the Crankshaft

generally calls for at least two engines, inasmuch as it has been found that much delay is avoided by having an extra engine ready for test in case of an accident occurring to the first one; however, when the design is considered unusually experimental, the contract generally is made for one engine with a rather large allowance for spare parts, which amounts almost to a second engine unassembled. After the construction of the engine is started, the detailed inspection generally is carried on by the contractor, but usually the plant is visited and the work looked over during the most interesting stages of construction.

Acceptance Tests

After the engine has been completed, the acceptance test is run, sometimes at McCook Field and sometimes at the contractor's plant, according to where the work can be done most conveniently. The nature of these tests is generally little more than a demonstration that the engine is capable of running at normal speed and firing on all cylinders. The more experimental or non-conventional the engine is, the less severe are the tests. This is due to an attitude on our part of being responsible for the design, since it has been checked so carefully from the start and since many basic changes are often incorporated. The acceptance test generally shows whether the engine has been constructed and assembled in a satisfactory manner and the engine is accepted or rejected on the basis of the results of this test. It undergoes the standard performance test at McCook Field.

Fig. 2—Magneto Coupling in Which the Rivets Have Been Sheared and the Splines Worn as a Result of the Torsional Vibration Transmitted from the Crankshaft

If the cylinder construction of the new engine is not of a well-proved type, the construction of the complete engine usually is held up pending the construction of one cylinder, the making of thorough tests of it on one of the universal test engines. These single-cylinder tests often show many troubles but, fortunately, most of them can be remedied by modifying the design or methods of construction. Frequently changes in the design of the valves, valve-guides or valve-gear are found necessary. Sometimes the compression-ratio proves too high or unnecessarily low, and the best location and number of spark-plugs as well as the proper spark-timing and piston clearance have to be ascertained. If the results with the single cylinder should prove too bad, the entire project would be held up indefinitely pending the design and development of a more satisfactory cylinder; or perhaps abandoned. Generally the results can be made satisfactory and the work proceeds.

We find that the single-cylinder tests are very satisfactory in everything but fuel-consumption. Fuel-consumption readings are only comparable with other single-cylinder results and are not comparable with results to be obtained from multi-cylinder engines. The writer is responsible for the use of these single-cylinder engines for this work and is endeavoring to carry the idea of testing "by units" much farther. In newly designed engines, the fuel-pumps, oil-pumps, water-pumps, ignition systems and carbureters can all be thoroughly tested in an accessories laboratory entirely independently of the rest of the engine. In one of the engines designed at McCook Field an entire gearcase assembly was tested to determine whether the complicated lubricating system was satisfactory. This was done by mounting it in the accessories laboratory and driving it at normal speed by an electric motor, using a thin oil of a viscosity similar to that of the Air-Service specification oil when at the working temperature. Faults in the oiling system were found much more quickly and cheaply in this way than by testing the assembly on a complete engine. Obviously, if enough parts of the engine can be tested separately at small expense and risk, the complete engine is far more certain of satisfactory results when assembled, and many costly wrecks can be avoided. It is believed that much more progress can be made along this line.

The Standard Test

When the completed engine is placed on the dynamometer at McCook Field ready for its standard performance tests, assuming that it has not been placed in good running condition previously, the procedure is about as follows: The engine is motored over with plenty of good oil and water circulating through it until the horsepower needed to motor it over at normal speed bears a predetermined relation to the horsepower to be expected from the engine, thus assuring satisfactory and standard conditions within the engine. Carbureter chokes are selected that will produce a satisfactory manifold depression when the engine is being motored over at normal speed. We do not deceive ourselves by running engines with large chokes and low manifold-depressions that are impractical in flight; therefore, the manifold vacuum is held between 1 and 2 in. of mercury. After this, the jets can be adjusted so that they meter an amount of fuel

FIG. 3—CRANKCASE THAT CRACKED IN SEVERAL PLACES WHILE UNDERGOING TESTS

in accordance with that to be expected per horsepower-hour, thus insuring a carbureter setting and mixture-ratio easily within the running range. Further adjustments must be made by actually running the engine under its own power, but the preliminary steps avoid much guessing at the start. Many other precautions are taken at this stage of the work but they are covered in detail in Engineering Division reports.[2]

As soon as the engine is running satisfactorily, steps are taken to improve its performance, if possible, and it is then put through the standard test planned to provide all the desired data on the performance of the engine. These include the obtaining of full-throttle-power and propeller-load-power curves, which give a good indication of the fuel-consumption in throttle flight; measuring the fuel and oil consumption; and the data needed by the airplane designer such as rate of water flow, water-temperature rise and the like. In case of failure of the engine during the standard test, parts that are affected are studied carefully and, if practicable, they are replaced and the test is continued. Fortunately, most of the engines we have developed have been able to get through the standard tests and at least get started on the long endurance test that follows. At the close of the standard test the engine is disassembled and inspected with the idea of ascertaining whether it is in shape, or can be put in shape, to start on the endurance test. If at the end of the standard test the engine is not in shape to start on the endurance test, it may be repaired, redesigned or abandoned, according to the results shown in the standard test.

[2] See Engineering Division reports Nos. 1506 and 1507.

The 50-hr. test is a standard method of comparing the durability of engines. It is a first step in developing an engine toward satisfactory durability. These tests are nearly always made on a torque-stand with a propeller

FIG. 4—PORTION OF A CRANKCASE IN WHICH THE DESIGN OF THE RIBS IN THE UPPER HALF WAS MODIFIED TO PROVIDE ADDITIONAL STIFFNESS

providing the load, and are based on the normal speed and power of the engine. A propeller is selected that will permit the engine to run at its normal speed with the throttle wide-open and absorb the normal rated power of the engine under these conditions. The 50-hr. test consists of 10 non-stop runs of 5-hr. duration, each run beginning with ½ hr. at full throttle and full speed with

FIG. 5—FAULTY DISTRIBUTION OF THE LOAD CAUSED THE FAILURE OF THESE CONNECTING-ROD BEARINGS

the propeller as described above and continuing for the remaining 4½ hr. when throttled down to the speed at which the propeller absorbs 9/10 of the power at full throttle. Due to the fact that in an airplane the engine generally is run for only 5 or 10 min. at anything approaching full throttle and is then throttled to a much lower speed when the airplane is taken up to an altitude at which the power output is greatly reduced because of the decreased density of the atmosphere, the 50-hr. test is much more severe than 50 hr. of flying; in fact, many Liberty engines flying as many as 180 hr. before overhaul are not in as bad shape as the same engine would be at the end of a 50-hr. test.

During the 50-hr. tests the gasoline and oil consumption and power fluctuations are noted carefully and the valves are watched for heating; in fact, the entire engine is watched carefully and an accurate record is kept of all troubles and of work that becomes necessary. Many troubles are encountered due to torsional or other periodic vibrations in the crankshafts, especially in those which are over four throws in length.• These vibrations result in the breakage of the gears used in driving camshafts or magnetos, of the magneto couplings and even of the magnetos themselves. Sometimes these troubles require several modifications before they are eliminated completely.

Fig. 1 shows a typical set of camshaft drive-gears that have suffered from such "crank-whip." A Hispano-type magneto-coupling in which the rivets have been sheared and the splines worn, due solely to torsional vibration transmitted from the crankshaft, is illustrated in Fig. 2. Fig. 3 shows a crankcase that was found to be cracked in several places, one of which is indicated by the arrows. A portion of a similar crankcase modified to overcome this weakness is illustrated in Fig. 4. Fig. 5 shows some connecting-rod bearings that have failed partially, due to the bad load distribution which was caused by unsatisfactory connecting-rod design. The bearings out of the same engine after another 50-hr. run with connecting-rods of a new design appear in Fig. 6. As will be noticed by comparing Figs. 5 and 6, the bearings in the latter show great improvement. Bearing No. 5 was injured by the breakage of a defective crankshaft. Fig. 7 illustrates some exhaust-valves that have suffered excessive wear on their tips and stems and from burning. In this case all these troubles were traceable to a defective rocker-arm design that imposed too much side-thrust on the valve-stems, an extreme instance of this type being illustrated in Fig. 8. Fig. 9 shows the valve-stem-guide bushings and Fig. 10 is reproduced from a photograph of the valves from the same engine after a 50-hr. run with a modified valve-gear that overcame the difficulty.

Some engines prove hard on spark-plugs, crack their water-jackets under the severe testing conditions, burn their valves and break minor parts such as valve springs, rocker-arms, oil lines and the like. Occasionally we have a serious wreck before the completion of the 50-hr. test; but in every case we endeavor to get 50 hr. of running if we possibly can, since this is not an acceptance test but a method of obtaining 50 hr. of a standard kind of wear on an engine so that its durability can be compared with that of other engines.

Tear-Down and Inspection

After the 50-hr. test, the engine is torn-down and inspected carefully. Most parts are inspected both before and after cleaning. All parts are removed to the photographic room where they can be inspected more accurately and can be photographed conveniently. The party that inspects the torn-down engine generally consists of the writer, a designing engineer, the test engineer assigned to the engine in question, the mechanic who has had the engine in charge and other interested persons. As they are examined the parts are checked off systematically from a printed list and the condition and appearance of each part is passed upon. We find that the appearance of parts means much. An agreement concerning each piece is usually reached before passing to the next one.

The help of the Materials Section at McCook Field has proved invaluable in arriving at the reasons for breakage and other kinds of material troubles. A decision as to what will be done about improving the part is withheld until after the receipt of the Materials Section's report. The results of the inspection or conference on the disassembled engine are noted and an agreement is reached with the designer or builder of the engine as to what should be done to meet the criticisms and recommendations. If the results warrant it, arrangements are made with the constructor to construct a modified engine in accordance with the recommendations made after the last inspection. We are glad to say that the engine, when reconstructed, accepted, given a check-run and the 50-hr. test, generally completes the test in a satisfactory manner. It is then torn-down again and inspected. When the need of additional improvements becomes apparent, they usually are made.

The photographs of parts of the first engine that were taken while the engine was torn-down at the end of the 50-hr. test are exceedingly useful for making compari-

Fig. 6—An Improved Form of Connecting-Rod Bearing

Fig. 7—Exhaust-Valves That Wore Excessively on Their Tips as a Result of a Defective Rocker-Arm Design

sons with the observed condition of the second engine, inasmuch as many different engines are handled by our organization and we may not carry in mind perfectly the conditions found in the engines from one test to another. After a sample engine has gone through one of these 50-hr. tests satisfactorily, it generally is considered good enough to warrant the purchase of 8 or 10 more for experimental use.

Flight and Service Tests

The first of these engines is put into flight test as promptly as possible, because usually an additional crop of troubles shows up when a new engine gets into the air for the first time. Such troubles as improper venting of the carbureter float-chamber may develop in flight because of changes in the relative pressures in the float-chamber and the throat of the carbureter while the airplane is moving at high speed. The distribution of the mixture may prove bad in sharp maneuvers, even though it may be satisfactory in normal flight. Occasionally, troubles in the water-circulation system appear when the airplane is in abnormal positions. Propeller-hub troubles are encountered occasionally, but the most troublesome point is vibration. Engines that seem to run smoothly on the test-block will shake badly in flight and cause trouble in the surrounding structure. Sometimes the accessibility of an engine does not prove to be as good after it is installed as it seemed to be on paper and on the test-block.

When an engine has reached the point where it has passed the 50-hr. test and is working satisfactorily in the air, and a few others of the same type are in use in the Air Service, it is time to try much longer tests of 100, 200 or even 300 hr. duration. These are of the nature of refining. The remaining weak points which did not show up in the 50-hr. test will begin to appear in the longer test and generally can be corrected then. It usually is possible to develop the engine so that it can run at higher speeds, higher compression-ratios or higher brake mean effective pressures, thereby effectively reducing the

Fig. 8—An Extreme Instance of the Ill Effect of the Side-Thrust That Was Imposed Upon an Exhaust-Valve Due to Improper Design of the Rocker-Arm

specific weight of the engine without increasing the difficulties of production or the cost, and at the same time insuring better fuel economy.

When a new type of engine is sent to some field where it has been unknown, many troubles may be encountered which are due to the fact that the personnel is unfamiliar with that particular engine. These might not have shown

Fig. 9—Valve-Stem-Guide Bushings Taken from an Engine after It Had Been Tested at McCook Field

FIG. 10—VALVES OF THE SAME ENGINE, FROM WHICH THE BUSHINGS SHOWN IN FIG. 9 WERE TAKEN, AFTER IT HAD BEEN SUBJECTED TO A 50-HR. TEST WITH A MODIFIED VALVE-GEAR

up during the tests at McCook Field. The maintenance conditions and methods at such a field are likely to be different from those where the engine was developed, and troubles of this nature may easily arise. Then, too, there seems to be a particular species of trouble that never occurs until the airplane gets out of sight of the airdrome. For example, parts will work loose that had never shown any signs of doing so on the dynamometer or block tests or even during the short flights around the airdrome. Another class of trouble is that due to the psychology of the pilot; in other words, to his lack of confidence in the new engine.

In the minds of the pilots, no engine is likely to be considered durable and reliable until it has gone through an experience of quantity production and wide use similar to that of the Liberty engine. Practically all engines have had their troubles when first put into use, and the Liberty engine is no exception. We are informed that due to its more hurried development the first 250 Liberty engines developed cracks in their crankcases; that the first 750 had light crankshafts, which occasionally broke, and weak connecting-rods. Since these weaknesses were rectified the engine has had such wide and satisfactory use that the pilots have long ago forgotten that phase of its development, and it now enjoys their greatest confidence.

In addition to developing complete engines, much work has been done in perfecting accessories that are not really parts of the basic engine but are fairly general in their application, such as carbureters, spark-plugs, piston-rings, valves and pistons. The results of this work have been applied to whatever engines could be benefited and have produced considerable standardization as well as improved performance. Between January 1919 and the present time development has been started on 23 engines. Of these two which were failures have been abandoned. Sixteen have been successes, and five which are not yet complete give promise of being successful.

COOPERATIVE FARM MARKETING

COOPERATIVE farm associations are not new, nor are they confined to California. They exist in various forms in every State in the Union. In California, however, their activities have been developed to a wider extent and on a more substantial basis than in any other State. Last year, according to an estimate of the State Market Director's office, farm products worth more than $250,000,000 were marketed through the cooperative associations of farmers who grew them. Roughly, this was about half the total market value of the State's output of farm products. It exceeded by many millions of dollars the value of products in any other State marketed by farm organizations.

It is generally conceded that the California farmer came through the readjustment period in much better shape than did the farmers in other districts. The Director of the War Finance Corporation said a few days ago: "The times we have been passing through since the war have shown the solidity of California. The banks have cared for the agricultural needs of California, and there has been little call for help upon the War Finance Corporation. California is setting an agricultural standard for the whole country."

In California one does not hear it argued that the banks should be run by "dirt farmers." Membership in a cooperative is limited to actual growers of the crop about which the organization is formed, but for sales managers, and other employes in the financial departments of the business, experienced business-men are hired, and they are not paid the wages of ordinary field-hands. Salaries of managers, who are business specialists and not necessarily farmers, run to $20,000 and $30,000, and in one instance as high as $50,000 a year, according to the reports that have been made to the Market Director's office.

The greatest progress in the farm cooperative movement in California has been in those organizations formed about crops requiring specialized skill in producing and marketing. Adversity has been the strongest stimulant toward collective action, and in general the growers who have the most difficult problems to solve in order to keep their crops on a profitable basis from year to year are the ones who hold together best. The greater number of California growers of food products are specialists and their organizations represent unified effort to solve problems common to comparatively small groups.

It should not be assumed that a cut-and-dried plan of cooperative organization, guaranteed against failure, has been developed in California. In a way, collective marketing is still in the experimental stage.—Monthly Review of San Francisco Mercantile Trust Co.

New System of Spring-Suspension for Automotive Vehicles

By H. M. CRANE[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* DIAGRAM AND PHOTOGRAPH

THE author indicates what the history of spring suspension has been but discusses only the conventional type of four-wheeled design in which the front wheels are used for steering and the rear wheels for driving and braking. The problem of front-axle spring-suspension is mentioned, but that of proper rear-axle spring-suspension, especially for passenger cars, is discussed in detail because it is a much more difficult one.

The advantages of the Hotchkiss drive for shaft-driven cars and some of its distinct disadvantages are stated, shaft-driven, rear-axle mountings being commented upon in explaining the factors that influenced the design of the spring-suspension device developed by the author. The advantageous features of this device are enumerated, inclusive of the effects of tire reactions.

THE first wheeled vehicles of which we have any record were not provided with any special spring members for the cushioning of road shocks. They were not entirely springless, however, for a certain degree of cushioning effect was furnished by the natural resilience of the materials used in the construction of the various parts. There are many horse-drawn wagons still in use today which embody this type of design. As road transportation became more highly developed and speeds increased, vehicles were produced in which the spring action of the various parts was increased by modification of the design, but still without the use of special spring members. The buckboard and the stagecoach are instances of this stage of development.

Near the end of the last century, however, the art of spring suspension, using steel leaf-springs of various forms, had reached a considerable degree of development, at least for horse-drawn vehicles. The early designer of automotive vehicles therefore had a valuable fund of information on this subject with which to work. This information could be used only in conjunction with the working out of an entirely new set of problems, imposed by the fact that the automotive vehicle is propelled, stopped and steered by means of its wheels. For the purposes of this paper, it will be necessary only to discuss the simple and conventional type of four-wheeled design, in which the front wheels are used for steering and the rear wheels are used for driving and braking.

In front-axle design, it is almost universal practice to pivot the wheels for steering by mounting the short stub-axles or knuckles, on which they revolve, on the ends of the axle by substantially vertical hinge-pins. The axle itself requires only to be connected to the frame in such a manner as to remain in a plane approximately at right angles to the longitudinal center-line of the chassis and so that a linkage can be arranged between the steering-gear, which is fixed on the chassis frame, and the steering connection on the axle, in a way that will allow of the axle moving relatively to the frame without tending to alter the direction of the front wheels. These requirements can be met fairly well by using a pair of semi-elliptic springs, fixed at one end and shackled at the other and, due to its simplicity, this is the favorite arrangement today. As I will explain later, this system is not ideal from the point of view of absorbing road shocks by the springs. It depends to a considerable extent for its success upon the pneumatic or other cushion tire, as well as on the fact that, in passenger cars, where easy riding is important, the passengers rarely are carried on the chassis at a point forward of the center of the wheelbase.

REAR-AXLE SPRING-SUSPENSION

The problem of a proper rear-axle spring-suspension, especially for passenger cars, is a much more difficult one. Like the front axle, the rear axle must be held in its correct position with respect to the frame, but it also must be supported in such a way that the rear wheels can drive or stop the car as required. Furthermore, the connection between the axle and the frame should be designed to minimize the transmission of road shocks from the former to the latter. A brief outline of the history of automotive design in this regard will help to make clear the questions involved.

In most of the early cars, the power was transmitted to the rear wheels by chains, either a single central chain or double side-chains being used. Let us consider only the latter type of construction, which clearly illustrates the principles of design. Rigid distance-rods are used between the axle and the frame. These are required to preserve the correct center distance between the driving and driven sprockets, and also serve to maintain the axle in a proper position with relation to the frame. Semi-elliptic springs, shackled at both ends, support the body load and also act to hold the axle laterally. In driving and braking the vehicle by the wheels, torque reactions are set up. In the type of design under discussion, the reactions due to driving or the use of a transmission brake are taken up in the jack-shaft housing. The reactions from the rear-wheel brakes are taken up in the springs sometimes, but more often by the distance-rods, which are then made stiff enough to act as torque-arms. In the chain-driven car, the rear axle is relatively light and has therefore no great tendency to produce shocks in the vehicle structure. This is not the case with the much heavier axle of the shaft-driven car, and this fact must be recognized in the design of the latter type if the best results are to be obtained.

The early shaft-driven cars tended to follow chain-driven designs, using distance-rods, and adding a torque-arm attached to the rear-axle housing and supported at some point on the frame to take care of the torque reactions arising from driving and braking. The springs were used only as supporting members, being usually mounted so as to turn freely on the axle, and being shackled at both ends. In striving for greater simplicity and decreased weight, it was found that the distance-rods could be dispensed with and their functions performed

[1] M.S.A.E.—Consulting engineer, New York City.

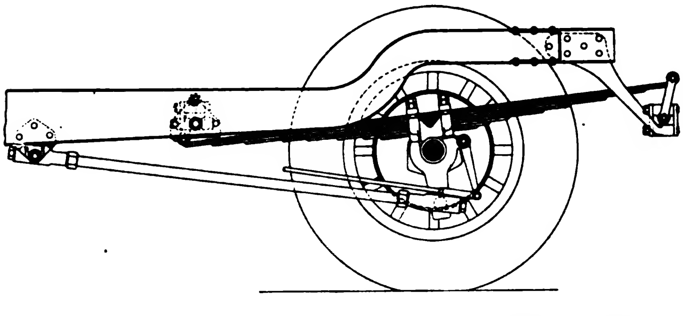


FIG. 1—SCHEMATIC DRAWING OF A RECENTLY DEVELOPED SPRING-SUSPENSION

by the front halves of the rear springs, the shackles at the front ends being abandoned and plain pivot-pins used in their place. A further move in the direction of simplicity led to the Hotchkiss drive, in which system the rear axle is entirely controlled by the rear springs. The springs support the load, maintain the axle in correct relation with the frame and absorb all torque reactions, whether due to driving or braking.

The Hotchkiss drive for shaft-driven cars has some very manifest advantages. It is light in weight and has a minimum number of parts to wear and rattle. It gives a cushioned resistance to suddenly applied driving and braking loads. Moreover, if the springs are properly proportioned, it maintains the center-line of the pinion shaft substantially parallel throughout the range of axle movement. This latter feature is of an importance not often recognized. If a rear-axle torque-arm is used, whenever the axle approaches or recedes from the frame the axle housing must rotate through an angle depending upon the amount of movement and the length of the torque-arm, the angle being greater the shorter the torque-arm is. If there is no lost motion in the parts, the pinion shaft must rotate to an amount depending on the angle through which the rear-axle housing turns, and on the gear-ratio. This would not be a serious matter if the pinion shaft alone were involved but, when the car is being driven by the engine, the pinion shaft is connected through the driving-shafts to the engine flywheel, which is a part of the system designed to turn as nearly as possible at a constant angular velocity. This combination of circumstances is capable of producing shocks in the driving members which are far greater than will be believed readily by those who have not observed this action.

The Hotchkiss drive has also some distinct disadvantages. When the rear springs are sufficiently flexible to give good riding, the resistance to torque reaction is too soft, with the result that, especially in lighter cars, the rear axle tends to jump when under heavy driving or braking loads and on soft or rough roads. From the point of view of good riding it leaves much to be desired. It furnishes a sufficient degree of flexibility in a substantially vertical direction, but is far too rigid otherwise.

Let us consider any of the present common types of shaft-driven rear-axle mounting, either of the Hotchkiss design or of designs using torque-arms or distance-rods, or both in combination. In practically all of these arrangements, the axle is positioned rigidly with respect to the frame in a longitudinal direction. If the weight of the axle were relatively small, this rigidity would not be a matter of serious moment. The fact is, however, that the weight of the rear axle and wheels of most shaft-driven cars approaches 10 per cent of the total loaded weight of the vehicle. The ideal of riding is to have the spring-borne parts of the vehicle, the frame, the powerplant, the body and the load, follow the major contour of the road surface without being affected by minor undulations. It would be desirable to have this condition apply also to the parts below the springs, the wheels and axles, and the pneumatic tires help to attain this result, but there is a limit to their ability in this direction unless made of extreme dimensions. Practically, the axles and wheels follow a very irregular course, with rapid and frequent changes of direction in a vertical plane. To change the direction of motion of a moving mass force must be applied and, if the mass is great and the change in direction sudden, that force must be large. In most cases the forces in question are the reaction of the road surface through the tire and the horizontal attachment between the axle and the frame such as distance-rods or springs. This latter connection is usually extremely rigid, and so it follows that the only cushioning for the shocks occasioned by these forces is furnished by the tires and what little resilience there may be in the road surface. Spring-cushioned distance-rods have been tried with a view to ameliorating this condition, but the cure in this form has seemed to be worse than the disease. Full-elliptic springs used in connection with the Hotchkiss drive are not greatly open to the above objection, but have the defect of being much more badly adapted to absorb torque-reaction loads than are semi-elliptic springs.

THE CRANE SPRING-SUSPENSION

With the idea of combining the simplicity and other advantages of the Hotchkiss drive with the proper cushioning of the shocks just described, the device illustrated in Figs. 1 and 2 was conceived. In addition, it appears in practice to remove two of the principal disadvantages of the Hotchkiss drive, by greatly increasing the resistance to torque reaction of any given set of springs without entirely removing the desirable cushioning effect to driving and braking shocks and, because of this fact, doing away almost completely with the jumping action of the rear axle on soft roads, already criticized.

Fig. 1, which is a schematic drawing of the arrangement, shows a semi-elliptic spring, shackled at both ends, and rigidly bolted to the axle. It shows also a distance-rod, the forward end of which is connected to the frame by a ball-and-socket joint and the rear end is connected to the axle by a similar joint, not at the center-line of the axle, but at a point substantially below the center-line, a

FIG. 2—APPLICATION OF THE SPRING-SUSPENSION ILLUSTRATED IN FIG. 1 TO A MOTOR-TRUCK CHASSIS

bracket rigidly attached to the axle being provided for the purpose. For clearness, only one end of the axle is shown on the drawing, the equipment of the other end being the same.

It is obvious that, with this arrangement, the axle is free to move longitudinally with respect to the frame as well as vertically, while at the same time it is constrained in both these movements by the resistance of the semi-elliptic spring. The vertical resistance need not be explained, being the normal spring action. The resistance to longitudinal movement is occasioned by the fact that, to translate longitudinally, the axle casing must rotate about the ball-and-socket joint located below the center of the axle. This rotation is resisted by a couple set up in the spring, tending to increase the load on one arm of the spring and decrease it on the other. The character of this resistance evidently can be varied by changing the distance of the point of attachment of the distance rod below the center of the axle. The spring shackles are made long enough not to interfere with this action. It is also necessary to provide for extra longitudinal come-and-go in the propeller-shaft connection.

In the conventional Hotchkiss drive, the torque reactions due to driving and braking are resisted by couples set up in the springs. This is still the case in this new arrangement, but the couples are of considerably less magnitude due to the action of the lever-arms to which the distance-rods are attached. The reduced twisting of the axle is very evident in actual driving, as is also the improved action over soft rough roads when using heavy power. The latter improvement undoubtedly is caused by the better method of taking care of the torque reactions and by a different type of tire reaction with this suspension.

Tire Reaction

This question of tire reaction is a very important one where the axle weight is high compared to the total weight of the vehicle. The pneumatic tire, especially one of the cord type, constitutes a most efficient spring. In other words it gives back practically everything that is put into it, with a minimum of damping action. The tossing about of such a weight between the tire spring on one side and the vehicle spring on the other certainly interferes with the smooth riding of the vehicle as a whole. This is why it is desirable to reduce the axle weight to the lowest possible figure. Unfortunately, it is not feasible in the case of the shaft-driven axle, even with the most careful design, to reduce the weight sufficiently to allow of ignoring it altogether. The new method of suspension, just described, is believed to provide a considerable improvement over conventional arrangements by reducing materially the maximum compression in the tire under any given set of operating conditions, and by giving an attachment between the axle and the frame that is cushioned in all directions except laterally.

One cause of excessive tire compression was partially explained in a previous paragraph that outlined the forces acting on an axle rapidly traversing a rough road. This action can be understood most easily by examining the action of an axle crossing a hump on the roadway. If rigid distance-rods are used, the momentum of the axle in a horizontal direction is augmented by that due to the total car-weight to a degree depending on the angle and the height of the hump. The reason for this is that the line of force through the wheel to the wheel hub and so to the axle is inclined at a considerable angle by the action of the hump, although this line is substantially vertical when the wheel is traversing a smooth level surface. The inclined force resolves into vertical and horizontal components at the axle center. The opposing forces are, vertically, the weight of the axle and wheels plus the pressure of the springs and, horizontally, the total weight of the vehicle. At low speeds, the momentum effect of the masses is relatively small. At high speeds, it is very great.

In a previous paragraph I called attention to the fact that the flat semi-elliptic spring is deficient in flexibility except in a vertical direction. This is due to its stiffness as a beam in a lateral direction and to its great torsional stiffness. The use of rebound clips, tying the plates more or less rigidly together, is a contributing factor to the foregoing. If all irregularities of the road surface were symmetrical and were crossed at substantially right angles by the axle and the wheels, the lack of flexibility in directions other than the vertical would be of no importance. Practically, however, the contour of the road surface traversed by the wheels on one side of a car is rarely the same as the contour of the surface traversed by the wheels on the opposite side. This fact in itself tends to cause lateral shocks. These are augmented by the constantly changing relation between the axle and the floor of the car which do not remain parallel but vary from parallelism by considerable angles in either direction. Such changing angular relation can be accomplished only by the springs or frame, or both, flexing both torsionally and laterally. Of course, this action tends to reduce what is commonly called "rolling" on curves and heavily crowned roads, but it does so at the expense of some severe strains and shocks in the parts involved, which produce an unpleasant jarring effect in the riding on cobble stones and similar road surfaces. It is the action just described that makes it so difficult to keep the rattles out of some of our modern passenger-cars. Actually, a very few thousandths of an inch of side-play of a spring in a shackle is sufficient to cause a most unpleasant noise.

Fig. 2 shows one method of improving this action where semi-elliptic springs are used on a passenger-car chassis. The springs are connected to the chassis frame at both ends by short links that allow of practically unlimited twisting and a limited amount of side swing. It is possible that this arrangement may give rise to an excessive amount of rolling, but tests so far made, with the chassis loaded as shown in the photograph, do not indicate this. To minimize the chances of rolling, the springs are carried as high as possible, being mounted above the axle. The springs are tilted down in front, so as to clear the doors and floor of the body. It is probable also that stiffer springs, that is, springs having a steeper scale in pounds per inch of deflection, can be used because of the better all-round cushioning effect obtained. One advantage of the full-elliptic type of spring is its better action in cushioning lateral shocks. If it were not for its weakness in resisting axle torsion, a lack of faith on the part of designers in regard to its ability to position properly the steering axle in heavy-duty service and its interference with low-hung bodies when used for rear-axle suspension, it might well become a popular type for passenger-car use.

The cord pneumatic tire, due to the low air-pressures that can be used successfully with it, has been the greatest single factor in improving the riding of automotive vehicles in recent years. The object of this paper is to call attention to the fact that there is still much that can be improved in the design of the other parts contributing to riding comfort.

Flighty Reflections

By C. L. EGTVEDT[1] SEMI-ANNUAL MEETING PAPER

PROPHECY having always been a forerunner of great things, we now expect any new and important development to have a prophetic introduction. As the engineer is seldom a "dreamer," his forecasts usually are not true prophecies but merely projections of the past into the future. Notwithstanding the great advance of aviation during the war, we now are beginning to realize that little real progress has been made since the original successes of the Wright brothers and Count Zeppelin, and inquiry is made whether the efforts of inventors are being directed along proper lines.

By comparing the weights and organisms of birds, insects and fish it became evident that their constitution is not essentially unlike that of land animals and that the only difference in their manner of locomotion came by the use of different mechanisms.

All efforts heretofore having been directed toward the perfecting of the stationary wing and high-speed propeller combinations in airplanes, the flight of only a small class of insects and soaring birds can be imitated and the versatility of other types, such as the fly and the humming bird, has not been approached. To obtain this freedom of action, the conclusion is drawn that we should incorporate in heavier-than-air machines all the features that nature demonstrates in the various forms of animal flight. Comparing the development of aircraft service to that of the locomotive and the automobile, the lack of proper landing-fields and aids to navigation is discussed and the question is asked whether we are not nullifying the advantages of air transportation by admitting that the requirements of present-day craft cannot be greatly improved and constructing exceedingly large suburban landing fields, rather than concentrating our efforts on the fundamentals of flight as exemplified in nature.

NO important movement in human affairs has ever come to pass without first having been introduced; and contemporary environment has always been gradually modified by advance pressure of the coming event, so that the arrival has never been a complete surprise. Each decade develops a crop of prophets, whose gift it is to turn their eyes to the future and preach the advent of that which is to come, influencing and molding the respective environment for its most favorable reception or building up reactionary forces to weaken the shock of the tidal wave.

Prophetic utterances are, as everything else in nature, the necessary effect of natural causes and generally these causes are strong demands or pressure arising from gradual changes in environment upon other factors of civilization that have lagged behind the average movement of events or fallen out-of-line too far ahead of the ranks.

The steam engine, the dynamo, wireless communication and the flying machine, at the time of their first reception by the general public, have all given rise to flights of fancy that over or undershot actual final accomplishment, but which at the same time urged the inventive brain to continual effort toward materialization of these prophecies, especially if made by men of accepted standing in the art. However, a broad vision and the ability to forecast are rather exceptional gifts and we are content to classify those who are afflicted with them as "dreamers." So regularly has prophecy been a forerunner of great things that we now expect prophecy before we expect anything new and important in the development of our affairs, and when we launch an enterprise that we hope will be a sensation, prophecy must introduce it. It has become almost a custom at the inauguration of the presiding officers of engineering societies to expect from the new leaders something prophetic. But the engineer is seldom a "dreamer." As a consequence we have had forecasts that are not true prophecies but merely projections of the past into the future. Definite outlines of research usually are given and it is due to these outlines that past art has in many cases been improved, but it is also due to these outlines that inventive effort has been constrained into definite channels. What if the guidance was misleading? What if the past efforts have been along a line not altogether based upon correct and scientifically sound principles?

When the Wright brothers and Count Zeppelin stirred the world by their first successful flights, it began gradually to dawn upon us that man would some day move through the air as easily and safely as a bird. Especially after the great advance immediately preceding and during the war did we expect that the complete conquest of the air was near at hand. Considering all this strenuous development in retrospect, we begin now to realize that we have achieved comparatively little in advance of the original successes of these first inventors. The present-day types of aerial vehicle differ very little from the original designs and we have assumed so far that no fault should be found with this conventional coordination of sustentation and propulsion as exemplified by the fixed wing or gas-bag and the screw propeller respectively.

THE FIRST INCENTIVE

Man received his first incentive for aerial locomotion when he recognized that birds or insects do not sustain themselves in the atmosphere by any supernatural agency but pay for their apparent defiance of the law of gravitation by the expenditure of energy. When people began to insist upon an explanation of natural phenomena, originally explained in an orthodox way by Biblical citations, and insisted upon an explanation on the basis of natural laws framed around the principle of conservation of energy, flight as exemplified by nature was scrutinized with increasing interest. It was, in the first place, discovered that the weight of the bird or insect is actually greater than the weight of the air that it displaces; and, secondly, it was found that the organism of these flying beings is not constituted so much differently from that of animals that move on terra firma as to make us suppose that they can store in their muscular tissues much greater amounts of energy in comparison with their weight than those animals. It became evident that the difference in the manner of locomotion came about only by the use of different mechanisms, but coordinated to the properties of the medium, air, so as to produce the desired motion in accordance with, and not in violation of, simple natural laws.

Action being understood to be equal to reaction explains that the force acting on the body of the bird in a

[1] Chief engineer, Boeing Airplane Co., Seattle, Wash.

vertically upward direction must be equal to a force exerted by the body in a downward direction and both these forces are equal to the mass set in motion times the acceleration of that mass. The upward force is equal to the mass of the body times the upward acceleration of the body and of the air that moves with it, and the downward force is equal to the mass of the wings and of the air moved by the wings times the acceleration of wings and air. Upward movement of the body and wings, or flight, could then be brought about only by an unbalance of acceleration and of the masses of air set in motion in favor of greater magnitudes involved in the downward movement of the medium air so as to overcome the force of gravity. Close analysis of the wing reaction upon the air, especially when the upward and downward movements are combined with the horizontal movement, reveals the fact that the air can be deflected in a downward direction during both the downward and the upward movements of the wings, provided the plane of the wing is deflected during its cyclic strokes so that it forms an angle of incidence with the air on its under side at all times. This is accomplished by inclining the wing on the downward stroke so that the leading edge remains at a lower elevation than the trailing edge and vice versa on the upward stroke. The wing motion of the bird is, however, not confined to motion in a vertical plane. In actual flight the tips of the wings describe an ellipse with respect to the axis of the bird body; or a cycloid with respect to their movement in the air. This means that the bird wing is brought forward at the top of the stroke and is again moved toward the rear at the bottom of the stroke. If it be assumed that the bird travels at the rate of 30 m.p.h. and that the wing motion along the path of the ellipse is uniform at the rate of 30 m.p.h., the return movement at the top of the stroke has a velocity greater than the velocity of the body of the bird in the air to the extent of 30 m.p.h.; hence, at the top of the stroke, the velocity of the bird wing in the air is 60 m.p.h. If, for a given airfoil area, the lift is proportional to the square of the velocity, the bird wing on its horizontal movement would have a lifting capacity four times the lift of a wing, which is considered fixed to a moving body, as, for instance, the wing of a bird in soaring or gliding flight, or the wing of an airplane. At the bottom of the stroke, the bird wing travels rearward at a rate of 30 m.p.h. The body of the bird is moving forward through the air at the same speed; hence, the relative motion of the wing in space must be zero. This condition of minimum velocity of the wing with respect to the medium lends itself ideally to the reversal of inclination of the wing chord, which changes, as above stated, from an upward slope from the leading edge to a downward slope from the leading edge during the downward and upward strokes respectively.

Function of the Wing Joint

It is important also to note the function of the wing joint of birds that allows the hinging of the outer extremity of the wing about a horizontal axis. Unlike a screw propeller, the point of maximum efficiency of which is about two-thirds the length of the radius from the hub, with the efficiency becoming less from that point radially inward and outward, the hinged-wing section of the bird can operate with the same efficiency from the hinges to the tip, if the velocities of the relative movements of the wing and the air and the wing profile are constant from the hinge to the tip, with no consideration of tip losses.

The above analysis will tend to indicate that the bird wing can perform the functions of both sustentation and propulsion and will indicate also that, only with great difficulty, after a series of refinements of design yet to be accomplished, would aerial vehicles of the present type approach the efficiency and versatility of movement in all directions that nature shows us are so well accomplished in the movable and flexible wings of the bird.

Insect flight seems to resemble more closely the mechanism of the airplane inasmuch as some classes of insect have separate mechanisms for propulsion and sustentation. The wing covers, usually made up of rigid tissues, are spread out in flight and held stationary while the wing membrane proper operates below these cover planes in rapid rotary motion resembling very nearly the motion of a screw propeller. This high-velocity movement causes impulses upon the air that are frequent enough to give rise to a musical sound.

Another class of insect does not possess the stiff wing-covers and both sustentation and propulsion are accomplished by the propeller action of the wings. These insects exhibit almost unlimited versatility in movements which vary from zero to maximum velocity in almost any direction with respect to the axis of the insect body.

The lighter-than-air machine finds its parallel in nature in the form of the fish. There are no organisms that can operate in the air on the principle of buoyancy, for the reason that we lack sources of lighter-than-air media that could be used against the force of gravity to advantage in vertical movement. The lightest gas so far known has about one-twenty-ninth the weight of air, whereas air has about one eight-hundredth that of water. Apparently nature could not accomplish the producing of aerial fish, a task that would be about $800/29 = 28$ times as difficult as the creation of water fish, even if hydrogen were ever present as a surface layer above our atmosphere. However, man has found a means of drawing rather easily the lighter gases from nature's unlimited resources and with this obstacle overcome has attempted the task of floating in the air in spite of the manifold difficulties of operation to which nature's organisms, fish, are not subjected, as, for instance, landing. It may be noted that flying-fish belong in the heavier-than-air class, being equipped with large pectoral fins that permit them to sustain flight for a limited period.

Up to the present time practically all efforts in aeronautics have been directed toward the perfecting of the stationary wing and high-speed propeller combinations, the airplane being capable of imitating the flight of only a small class of insects and the soaring flight of birds when the propeller is inactive. Attempts have been made in the helicopter to simulate the flight of insects of a more versatile type, which depends upon propellers only for sustentation and propulsion; but great difficulty has been experienced in providing sufficient control for the purpose of directing the propeller thrust in other than a vertical direction. It also appears that to depend upon sustentation by propeller action alone takes away the feature of safety, a feature that is never entirely realized in our complex combustion engines so much as it would be in a fixed wing truss composed only of parts at rest with respect to one another.

Importance of Versatility

It appears that with the development of the airplane only a small step has been made in the way of accomplishing satisfactory flight. We should incorporate in our heavier-than-air machine all the features that nature demonstrates in her various forms of animal flight to give us the same feeling of being perfectly at home near

the clouds that we observe in the graceful and playful motion of the birds or the dancing flight of the fly, or of the humming-bird hovering in the atmosphere, apparently without effort, darting to the right or the left or forward with a rapidity and ease that will be envied by the human aeronaut until he can do the same.

It further appears that we have been trying to perform successful commercial operations without questioning to any great extent our present operating mechanisms. Sustentation has been provided by forward motion except in the case of lighter-than-air craft in which sustentation is obtained by principles of buoyancy alone, or in combination with a forward movement. In this manner we have accomplished sustentation but with an apparent lack of versatility in the application of energy. Instead of being able to sacrifice propulsion to aid sustentation at the lower speeds and to sacrifice sustentation to aid propulsion at the higher speeds, we find our propelling force decreasing with the increase of the speed of advance and our sustaining surfaces greater than we can efficiently use at these higher speeds. Are natural flight requirements solved in this manner, or does nature utilize energy with greater discretion? Although the history of flight does not show that a flexible propelling mechanism has ever been operated successfully, we are not in a position to say that this means of propulsion may not be accomplished in a manner that will advance materially our efforts to produce satisfactory flight.

When considering flight from the point of view of those engaged in the construction of aircraft, a number of questions arise which indicate that the art must advance before stability can be expected. Can we truthfully say that the actively thinking public is satisfied with flight as exemplified by the past and present art, or are we still confronted with the problem of solving flight in a manner that will produce absolute confidence and provide genuine service? If the former were correct, we should have little difficulty in constructing and marketing our products. However, if the latter is correct, shall we try to force the building of existing types or develop new aircraft art?

Recalling some of the principal methods of transportation, we note that it was approximately 50 years after the invention of the locomotive before the service offered was acceptable to the extent of making the railroads pay. More than 20 years of development was necessary to provide the service the general public required from the automobile. We believe the public of today has a greater knowledge and appreciation of mechanical progress and is learning to accept it more readily; yet, if we realize that mechanical flight was accomplished in 1903, we must admit that willingness to accept is prompted by some other reason than a new public viewpoint. The general public has learned to invest in service and only a few persons are willing to invest in limited service. In a spirit of desire to provide service, we attempt to analyze the present conditions that indicate limited service and, turning to aircraft operation, we find our present types hampered by the lack of proper landing-fields and aids to navigation. It is true that efforts expended in this direction would greatly improve the service now obtainable, but are the requirements for landing-fields reasonable, or are we partially nullifying the advantages of air transportation by the necessary construction of exceedingly large suburban landing-fields? Are we satisfied that the requirements of our present craft cannot be very greatly improved, or are we planning to concentrate our efforts on fundamentals of flight to approach more nearly the flight exemplified in nature?

We have constructed in our aircraft advance the airplane, the airship, the helicopter, the ornithopter and the free balloon; and have improved them in varying degrees until it appears that it is very easy for us to continue these developments. So long as these developments indicate reasonable improvement, we are not likely to question the fundamentals of our work or attempt widely different fields of exploration unless forced to do so. We have advanced and are progressing at present, but the progress at present is largely the same as that of the general automotive industries; and if we were to analyze carefully the development of aircraft since controlled flight was first accomplished, would we find the greatest advancement in the methods of sustentation and propulsion, or in the coordination of structural units and the employment of improved structural materials and advanced methods of construction?

WELFARE WORK

WE are trying to ameliorate the prejudice that has grown up between employer and employe. We want them to feel better toward each other than they have in the past. One way is to teach the employe that the employer cares for him. That is one function of the welfare work. It is to instil in the minds of working men that they are not working machines, that they are not to be scrapped like iron and steel, but that they are human beings and have human souls. What does God Almighty care whether a man is worth $1,000,000 or 10 cents? What we are trying to teach is brotherhood. We are trying to instil in the minds of employers that they have duties toward their employes; that the mere possession of capital is a trust; that the carrying on of business is a trust, and that the human beings they employ are entitled to be considered as brothers. But in teaching this we are also teaching the working men that they should be brothers to each other, and learn to regard their employers as friends.

What would you do if you were a day laborer and all there was for you on earth was to work hard all day, go home tired, get your dinner and go to bed, only to waken the next morning to repeat that routine day after day for the remainder of your life? Then what would you say if you were a little higher in the scale, a mechanic, for example, and had to make the same things, work on the same piece of metal day in and day out; that all you had to look forward to was getting up in the morning and doing something you did not care to do, doing it all day, and all the change you had from that mechanical routine was the little social enjoyment you had with your family and your children and going to the movies? How would you feel under those circumstances? Then let us go a step higher. Suppose you were a banker and all the work for you to do was to go to your office and scheme out how to get the best of some other man; how to make money for yourself and your bank, and to get engagements to float securities and then how to sell? Suppose you were scheming to do that all the time, and every day had that routine of collecting and disbursing money. What would your life be? There are many sterile souls among the leading men of this country, many among the commercial men, among the mechanics and among the laboring people.—Haley Fiske.

Airplane Performance Formulas

By Edward P. Warner[1]

Semi-Annual Meeting Paper *Illustrated with* Charts

AERODYNAMIC analysis relates mainly to questions of performance and stability, the latter including both maneuverability and control, but the designer's problems concern chiefly the prediction of the best possible performance. Accurate analysis, which would include a summation of the elemental resistances of an aircraft part by part and the making of many corrections, supplemented by tests of models in a wind-tunnel, involves much labor and expense.

When a preliminary choice of dimensions and specifications for a new type of an airplane is to be made or there is a question of the performance attainable with a given load and power, a shorter method becomes necessary. This is to be found in the derivation of simplified formulas and graphs.

The author illustrates by examples the process of deriving these formulas and considers in turn such elements as minimum and maximum speeds; climbing ability and the conditions under which an airplane will have a zero ceiling, that is, the limiting conditions under which flight is possible; rate and angle of climb, the latter controlling the possibility of getting out of a small field over a barrier; and the best ceiling possible. Under these heads he takes up such questions as fineness, which is the ratio of the parasite resistance to the wing area; and lift, weight and power and their relations in determining the various coefficients which are used. Values obtained theoretically from the formulas were checked by comparison with those of about 50 airplanes of various types of which the measurements and performance are known and application is made to specific examples. Numerous curves show the relation of the various coefficients that enter into the design and performance of the airplane.

THE aerodynamic analysis of airplanes and that portion of airplane design dealing with the practical applications of aerodynamic theory divide naturally under the two heads of performance and stability, stability being taken to include maneuverability and control. A large share of the designer's problems, therefore, pertains to the prediction of performance and to the determination of a design that will give the best possible performance.

The analysis of performance may be carried out by several methods, the more refined and accurate of which involve much labor. To obtain a really accurate estimate of the speed or climb of an aircraft necessitates the summation of the elemental resistances part by part and the making of many corrections for such factors as the slipstream, the inclination of the thrust axis, interference between the parts of the structure, and the like. The labor involved, while justified in a final calculation, is too great to be undertaken lightly when preliminary estimates of performance are to be made or when a number of different possible arrangements of the parts of a machine are to be compared with respect to their aerodynamic qualities.

A much simpler device for approximating performance involves the use of a wind-tunnel test of a complete model. This is less accurate than the method of direct calculation, as the wind-tunnel model is so small that it is impossible to make it a true scale reproduction of a full-sized machine in every particular. A multitude of such items as fittings and stranded wires, small individually but of importance in the mass, are therefore omitted from consideration. Even if it were possible to include such parts, the scale effect would be so enormous that the results obtained by the usual method of scaling in proportion to the square of a linear dimension and to the square of the speed would give incorrect results. A wing made to 1/20 scale may logically be expected to give very nearly 1/400 the lift and drag of the full-sized wing at the same speed, but the results that would be obtained by attempting to make a 1/20-in. scale model of a cable ⅛ in. in diameter or of a honeycomb radiator would be almost meaningless and certainly would not repay the vast amount of effort involved. Furthermore, the wind-tunnel does not allow for the making of a correction for slipstream effect, a very important factor in the resistance of an airplane. On the whole, it is rather remarkable that notwithstanding these obvious and manifold disadvantages it is still possible to secure a reasonably close approximation to the performance of an airplane by a single test of the lift and drag of a complete model in the wind-tunnel. The results for maximum speed are somewhat better than are those dealing with climb, as the slipstream effect, ignored in the wind-tunnel test, is of relatively more importance with reduced air-speed and open throttle, which is a climbing condition, than at maximum speed in level flight.

The wind-tunnel is very valuable and it is difficult to imagine where we would find ourselves today in aeronautical engineering if no tunnel tests of complete models had ever been made. Certainly our knowledge of stability, as well as our ability to predict performance, would be on a far lower plane than they have actually attained. Entirely aside from any discussion as to the theoretical merits of wind-tunnel testing for performance, however, it is evident from practical considerations that such tests cannot be made in all cases. Lack of time and money often forbids the making and testing of a wind-tunnel model, just as it often prevents the carrying out of elaborate performance calculations.

When a new type of airplane is to be designed and when the engineer is confronted with the necessity of making a preliminary choice of its general dimensions and specification, or when there is put up to him suddenly the question of the performance attainable with a given load and power, there is no opportunity to refer the problem to the wind-tunnel or to cover reams of paper with tabulations of resistance. Some shorter method becomes necessary and that shorter method can be found, assuming that the designer's experience with similar types is not sufficient to enable him to guess the performance offhand, only in the derivation and use of simplified

[1] M.S.A.E. — Associate professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

performance formulas or of graphs that represent formulas too complex to be readily expressed in analytical form.

Classification of Performance Formulas

Performance formulas may be divided into three principal groups, (*a*) those based solely on experience with airplanes previously constructed, (*b*) those based on rational considerations alone, or perhaps combined with the data drawn from wind-tunnel tests, and (*c*) those which depend on a combination of theory and practice. Up to the present time, the first-named class of formulas has held the premier place and has often proved of great value. These formulas have dealt with the maximum and minimum speeds, with the rate of climb and with ceiling and with every other conceivable element of performance. They have been no less diverse in their origins than in their purposes. Nevertheless, it is difficult to fit a purely empirical chart or formula to the solution of a problem so complex as that of the flight of an airplane in such a way as to be sure that allowance is made for all the variables that may affect the solution. Only by the use of a modicum of theory can we feel certain that we have omitted from consideration in our formulas no variables that should be included and have included none that are unimportant. This does not imply that pure theory furnishes a satisfactory basis for the derivation of formulas, as it cannot do so in the present state of our knowledge. It is always necessary to depend at some point of the reasoning on experience either in the wind-tunnel or in free flight, but theory has great use in guiding our research and of reducing the probability of going astray in the quest for data. The acid test of any formula is application to existing machines for which the true performances have been determined.

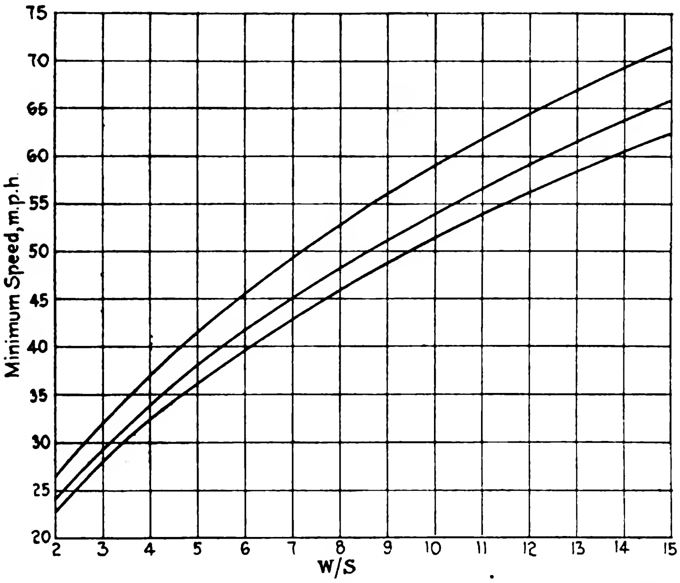


Fig. 1—Curves of Minimum Speed as a Function of the Wing Load

The nature of the formulas that can be secured by a combination of rational derivation and of experimental data can best be illustrated by actually following through the process of deriving such expressions. By taking up the elements of performance one by one and determining first the form into which formulas should be cast and the variables involved, actual numerical expressions are obtained which give, as far as possible, the performance of an airplane in terms of its well-known dimensions and other characteristics.

Minimum and Maximum Speeds

The first and the simplest element of performance to be treated is minimum speed. In virtually all instances the true minimum speed of an airplane in steady flight is determined by the wing-loading and the magnitude of the maximum-lift coefficient. The only exception to this rule is found in the case of airplanes whose reserve of power is so small that the horsepower required to maintain steady horizontal flight at sea level and at the angle of maximum lift is greater than the power available under those conditions, and whose ceiling is so low that it could only be regarded as a freak unsuitable for serious consideration. It should be borne in mind, although it is perhaps hardly necessary to emphasize the fact, that the minimum speed that is calculated from the maximum-lift coefficient and the wing loading is the true minimum, and not the minimum speed that is often reported in performance tests as being obtained by closing the throttle until the airplane is no longer able to maintain level flight. The speed of minimum power is far from being the true minimum speed, the latter being determinable in level flight only by keeping the throttle well open and stalling the machine to such an angle that it is barely able to fly level but staggers along at an angle of attack of 18 deg. or thereabout. Few pilots have ever made a serious attempt actually to reach or to maintain the true minimum speed of flight.

If it be accepted that maximum-lift coefficient and load per unit area are the only critical factors in minimum speed, it should be easy to derive a formula in terms of these quantities. Writing the fundamental equation of lift

$$L = L_c S V^2$$

where

S = the wing area
V = the speed of flight
L = the total lift

the equation can be given a form applicable to this special problem by taking the particular values V_{min} and $L_{c\ max}$ for V and L_c respectively and by substituting W, the weight of the airplane, for L, the lift being equal to the weight in steady horizontal flight. If this be done, the equation of minimum speed takes the form

$$V_{min} = \sqrt{(W/L_{c\ max}\ S)} = \sqrt{(1/L_{c\ max})} \times \sqrt{(W/S)}$$

It remains then only to assume a value of $L_{c\ max}$. If V is given in miles per hour, the values of $L_{c\ max}$ range from 0.0026 to 0.0045. On substantially all modern wing-sections, however, with the exception of a few thick sections used for cantilever wings only, the value will be found to lie between 0.0029 and 0.0038, the higher values appertaining to thick sections and to those with strongly concave lower surfaces. Solving for $\sqrt{(1/L_{c\ max})}$ we see that

$$\sqrt{(1/0.0029)} = 18.6 \text{ and } \sqrt{(1/0.0038)} = 16.2$$

The formula for minimum speed is thus found to be

$$V_{min} = K_1\sqrt{(W/S)}$$

where K_1 is to be chosen somewhere between 16.2 and 18.6, depending on the general type of wing-section employed. If nothing is known about the wing-section to be used, a rough but nevertheless useful approximation to the landing speed is given by the formula

$$V_{min} = 17\sqrt{(W/S)}$$

In Fig. 1 curves of minimum speed as a function of W/S are plotted for the maximum, minimum, and mean values of K_1. Claims of landing speeds materially lower than

those shown by the curves should be viewed with strong suspicion.

The maximum speed offers more complex problems than the minimum, as not only the weight and area and the properties of the wing-section but also the power and the parasite resistance are involved. In attempting the derivation of a rational expression the most convenient and most reasonable simple assumption is that the angle of attack at maximum speed corresponds to the angle of minimum-drag coefficient of the wing. Wind-tunnel tests and free-flight work unite in showing this assumption to be close to the truth in most cases. A small change in the angle of attack at the maximum speed, however, has little effect, as the drag-coefficient curve is ordinarily very flat in the neighborhood of the minimum drag. If this assumption be true it is evident that a small change in the angle will have a negligible effect on the drag coefficient, which can then be considered as keeping a constant value. If the drag coefficient of the wings is considered as remaining constant, the coefficient of total resistance may also be taken as a constant, since the change of the parasite resistance coefficient with the angle of attack is obviously small. The equation of the power required at maximum speed may then be written

$$P = (D_c S + R_c s)\ (V^3_{max}/375)$$

where

D_c = the coefficient of wing-drag
R_c = the coefficient of parasite resistance
S = the wing area
s = the parasite resistance area
V_{max} = the maximum horizontal speed in miles per hour

both of these being assumed to remain constant. The power required for level flight at the maximum speed is, of course, equal to the power available, which is the product of engine power and propeller efficiency. Taking the propeller efficiency, which is denoted by η, also as invariable, the equation can be transposed into the form

$$V_{max} = \sqrt[3]{[(P_o\eta) \div (D_c S + R_c s)]}$$

If the ratio of parasite-resistance surface to wing area then be taken as a constant, that is, if the fineness be assumed the same in all cases, the equation becomes

$$V_{max} = \sqrt[3]{[375\eta \div (D_c + R_c[s/S])]} \times \sqrt[3]{(P_o/S)} = K_2\sqrt[3]{(P_o/S)}$$

The rather surprising conclusion is thus reached that, given a certain fineness of design, the maximum speed of an airplane is independent of its weight, provided the machine flies at its maximum speed very close to the angle of minimum drag of the wing. This condition, as already noted, is realized in high-speed airplanes and the few comparative tests made on such machines with different loadings actually show the speed at sea level to be practically unaffected by small changes in weight.

It would, of course, be possible to find the value of K_2, as that of K_1 was determined, by assuming values of D_c, R_c, and s/S and solving directly for the constant, but it is easier and more accurate to call in the assistance of free-flight tests at this point, plotting the values of P/S and of V_{max} against each other in such a way as to determine the value of the constant. This can be done most conveniently by plotting V_{max} against P/S on logarithmic paper, as the curve obtained in that way serves not only to determine the value of K_2 but also to check or to disprove the deduction that the speed varies as the cube root of the power-area ratio. The characteristics of 65 machines have been plotted in this way in Fig. 2 and the best mean straight line drawn through the group. It is found that, when the slope of the line on the logarithmic chart is measured, the slope is not truly ⅓ but 0.39. The best average straight line corresponds to the equation

$$V_{max} = 127\ (P/s)^{0.39}$$

The two lines parallel to that of best average denote speeds 10 per cent higher and 10 per cent lower, respectively, than those given by the formula. The maximum departures from the formula were found to be 12 per cent high and 17 per cent low for land planes, while the speeds of flying-boats, which are denoted by crosses in Fig. 2, uniformly fell below the speeds calculated by the formula, the maximum discrepancy being 23 per cent. This was to be expected, as the fineness of flying-boats is in general inferior to that of land planes.

The average difference between the speeds calculated by the formula and those found on actual test was 6.2 per cent for all the machines and 5.4 per cent for the land planes alone. These errors may seem large, but the chart includes points for airplanes as diverse in their characteristics as the old JN4D, the Air Service Messenger, the commercial Junkers, the Verville-Packard racer, and the Trans-Atlantic NC boat. In view of the extraordinary range of fineness represented among the machines used, the maximum departure from the mean curve is not excessive. The average errors just mentioned are a good measure of the probable error in using the formula or curve if no attempt is made to allow for differences in fineness. The probable error can be much reduced, however, if some attempt is made to estimate the fineness of an airplane and to modify the constant in the formula accordingly. It is obvious by a glance at

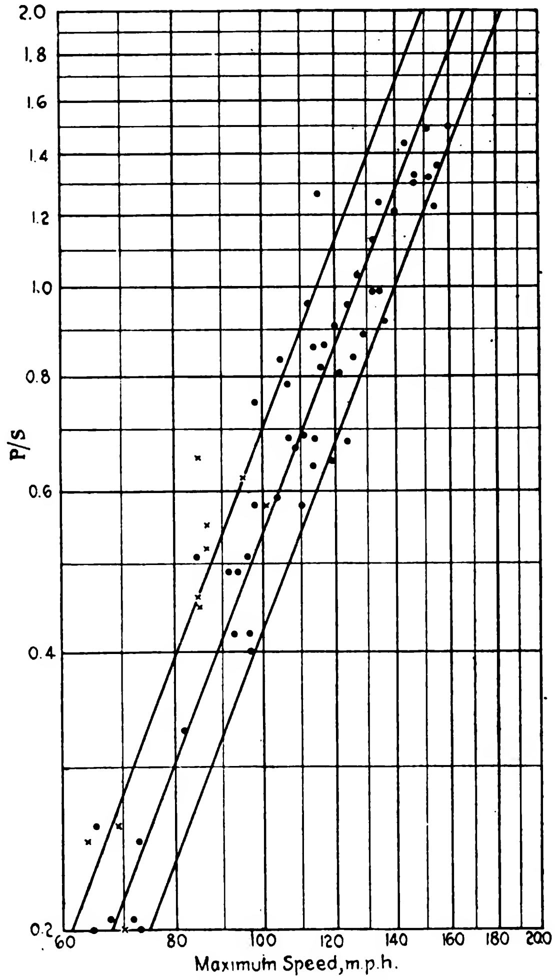


FIG. 2—CURVES SHOWING THE CHARACTERISTICS OF 65 MACHINES AS REGARDS THE RELATION BETWEEN THE POWER AND MAXIMUM SPEED

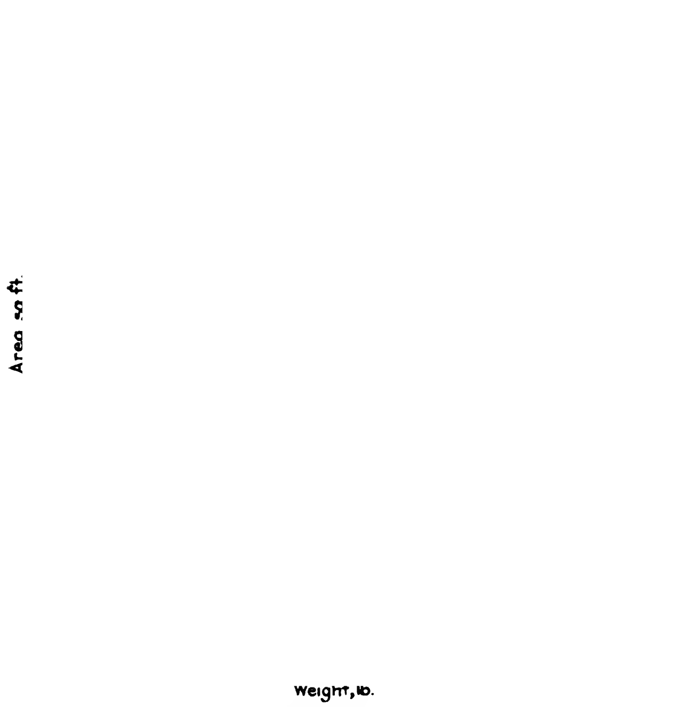


Fig. 3—Curves of the Minimum Power Necessary for Flight Plotted in Terms of the Weight and the Area

some airplanes that they have more parasite resistance than the average for their type, while others have correspondingly less. The exercise of a little judgment in this respect materially decreases the amount of error liable to appear.

The reason for the choice of the exponent 0.39 in place of 1/3 calls for a few words of explanation, as this change may appear to invalidate all the theory that has been given and to reduce the whole matter once more to guesswork and empiricism. The variation of the exponent is, however, very logical and indeed might have been expected in view of the assumptions made. In the first place, the assumption was made that the airplanes treated by the formula were all to fly at maximum speed at the angle of minimum-drag coefficient. While it has been seen that this is substantially in accordance with the facts for pursuit and racing airplanes, it is far from representing the true conditions of flight for commercial and heavily loaded bombing craft. Machines of these types fly at maximum speed at angles higher than that of minimum drag, and the wing-drag coefficient is therefore greater than for the small fast types. It is logical to expect then that a decreasing value of P/S will cut down the maximum speed more rapidly than would be indicated by a theory based on minimum-drag coefficients in all cases. Furthermore, the derivation of a single formula for the maximum speed rested on the implicit assumption of equal fineness for all machines. This, of course, is far from the truth and it is found in general that the best fineness, or the lowest values of R_Cs/D_CS, occur in fast machines having high values of P/S. This again would indicate the probability of such an increase in the exponent of P/S as has actually been found.

A number of other empirical and semi-empirical formulas have been derived for the purpose of finding maximum speed, and a few may be cited for comparison with that just discussed. Bairstow, for example, gives the expression

$$(V_{max} - 55)^2 = 1445\ [(40 \div [W/P] - 1)]$$

for a constant wing-loading of 7 lb. per sq. ft., and the report of the British Advisory Committee on load factors for aircraft presents the alternative formula of similar type

$$([\sqrt{V_{max}} \div \sqrt{(W/S)}] - 25)^2 = 196([84.8 \div ([W/P]\sqrt{[W/S]})] - 1)$$

This applies only to single-engine land planes, the values of the constants being changed for other types. Comparison of these two formulas shows a remarkable agreement in view of the modification of the constant, the results being the same within 1 per cent for all reasonable power loadings. Both the British formulas give maximum speeds from 7 to 10 per cent higher than that which I have proposed in this paper. The general agreement in the nature of the change of maximum speed with power loading and wing loading is, however, good; the difference between the results from the Advisory Committee's formula and those from the one derived here being nearly uniform throughout as can be seen from Table 1.

TABLE 1—COMPARISON OF AIRPLANE SPEEDS CALCULATED BY DIFFERENT FORMULAS

		Maximum Speed by Formula, m.p.h.		
			British Advisory	
W/P	W/S	Bairstow	Committee	Warner
7	7	137	136	127
8	7	131	130	121
10	7	120	120	111
12	7	113	113	103
15	7	104	104	95
20	7	93	94	85
9	9	..	136	127
6	6	..	132	127

An American aeronautical engineer has recently devised a maximum-speed formula which has not yet been published, and which I am not at liberty to quote, but which appears to give better results than any of the others that have been mentioned.

Climbing Calculations

After minimum and maximum speed, the most interesting application of formulas is in connection with climb calculations, particularly in the determination of the conditions under which an airplane will have a zero ceiling or, in other words, the limiting conditions under which flight is possible.

The first step in the determination of any climb formula must be the securing of information about the dependence of the minimum power required on the characteristics of the airplane, since all climb calculations depend on the amount of power required for horizontal flight. Such a relation can be obtained by making certain approximations as to the speed at which the best climb is to be secured and as to the L/D of the airplane under climbing conditions. If the L/D is known, the resistance in steady flight can obviously be obtained from the formula $R = W \div (L/D)$ and, if the air speed for the best climb be assumed to be given by the relation $V_1 = K_{min}$, the minimum power required for flight is evidently equal to $WKV_{min} \div (375\,L/D)$, V_{min} being given in miles per hour. Substituting the expression already obtained for V_{min}, this formula becomes

$$P_{req} = [KW \times K_1 \times \sqrt{(W/S)}] \div [375(L/D)]$$

The horsepower available is of course equal to $P_0\,\eta$, and it is therefore necessary only to choose values for K, K_1, L/D, and η in order that formulas for the approximate solution of all climb problems can be obtained. In particular, it is evident that the limiting condition under which flight is possible is that in which the horsepower available and the horsepower required are equal at sea level, or that in which

$$W/P \times \sqrt{(W/S)} = [375(L/D)\eta] \div K_1K$$

At the angle of best climb, wind-tunnel tests and such free-flight information as is available alike indicate that the L/D for a complete airplane may be expected to lie in the neighborhood of 7.5. It has already been seen that 17 is the average value of K_1. The propeller efficiency under climbing conditions may be taken as 70 per cent. Finally, experience shows the climbing speed of an airplane to be on the average 35 per cent greater than the minimum speed, and K may thus be taken as 1.35. Combining these factors, the equation for horsepower required becomes

$$P_{req} = 0.0082\, W \times \sqrt{(W/S)}$$

and the limit of possible flight is given by the condition

$$(W/P) \times \sqrt{(W/S)} < 85.9$$

The minimum power necessary for flight in accordance with this formula is plotted in Fig. 3 in terms of weight and area. The full lines in Fig. 3 represent various engine powers, while the dotted lines are loadings in pounds per square foot. The application of the chart is simple. If, for example, it be desired to find the minimum power with which a total load of 3000 lb. can be carried without going to a wing loading of less than 4 lb. per sq. ft., the power is read off at the point corresponding to 750 sq. ft. and 3000 lb. and found to be 69 hp. If a reserve of 25 per cent of the total horsepower is desired as a minimum, it is deduced that the minimum practical power with which such a machine could be taken off the ground would be 69 x 4/3 or 92 hp. Similarly, if we seek to find the maximum load that can be carried by a 100-hp. engine with a wing loading of not less than 6 lb. per sq. ft., the result will be found at the intersection of the full line marked 100 and the dotted line representing 6 lb. per sq. ft. This intersection corresponds to 3500 lb. and 585 sq. ft.

The rate of climb is determined by the familiar method

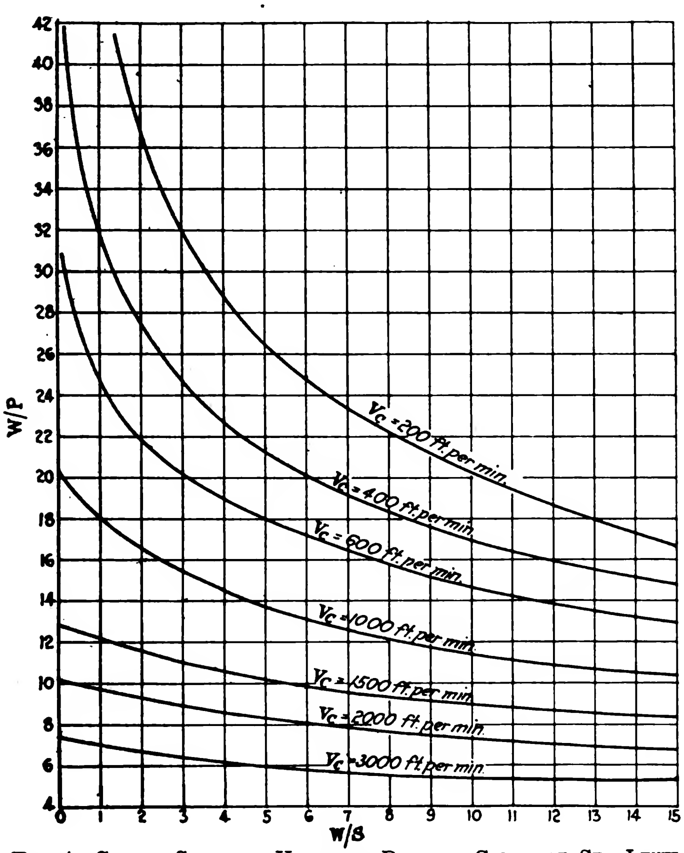


FIG. 4—CURVES SHOWING HOW THE RATE OF CLIMB AT SEA LEVEL SHOULD VARY AS A FUNCTION OF THE LOADING PER SQUARE FOOT AND THE LOADING PER HORSEPOWER

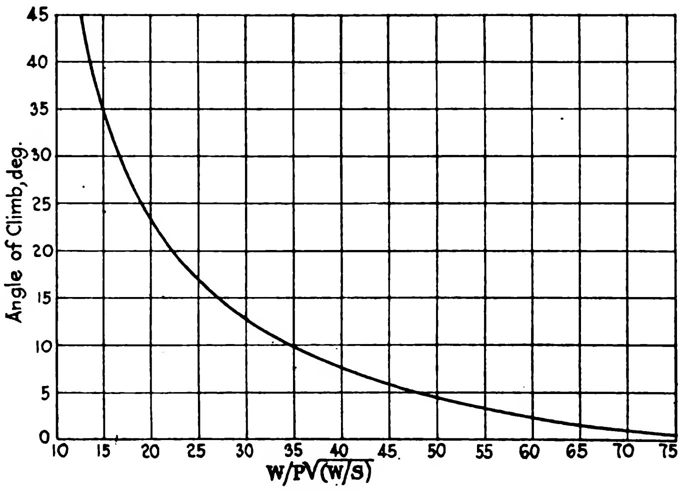


FIG. 5—RELATION BETWEEN THE ANGLE OF CLIMB AND THE WEIGHT

of dividing the excess of power available over the power required by the weight of the machine. The rate of climb in feet per minute at sea level should therefore be given by the formula

$$V_c = 33{,}000\, [(P/W)\eta - 0.0082\sqrt{(W/S)}]$$

In this connection it will be wiser to take 65 per cent rather than 70 per cent as the propeller efficiency in climbing, since the machine that is barely able to fly will have its propeller designed for the one speed at which it can get off the ground, while the airplane with a more normal climb and reserve of power has its propeller designed for a speed nearer the maximum and therefore works more inefficiently under climbing conditions. Taking account of this the expression becomes

$$V_c = [(21{,}400 \div [W/P]) - 271\sqrt{(W/S)}]$$
$$= [271 \div (W/P)] \times [79 - ([W/P] \times \sqrt{[W/S]})]$$

Fig. 4 shows how the rate of climb at sea level should vary as a function of the loading per square foot and the loading per horsepower.

Another performance factor of interest, especially in commercial airplanes, is the angle of climb, which controls the possibility of getting out of a small field over a barrier. The sine of the angle of climb is, of course, proportional to the ratio of the climbing speed to the air speed. The formula for the climbing speed is given just above and it has been seen that the air speed in climb may be taken as 22.9 $\sqrt{(W/S)}$ in miles per hour, or 2015 $\sqrt{(W/S)}$ in feet per minute. The formula for climbing angle therefore becomes

$$\sin\theta = (10.62 \div [(W/P)\sqrt{(W/S)}] - 0.135)$$

A curve of θ against $(W/P)\sqrt{(W/S)}$ is plotted in Fig. 5.

CEILING FORMULA

The determination of the formula for ceiling in terms of weight, area and power alone requires some preliminary analysis in order that the ceiling may be found in terms of the horsepower available and the horsepower required at sea level. It is well known that the minimum horsepower required for flight varies inversely as the square root of the air density, and it has been found by experience that if an exponential relation is required a satisfactory approximation to the variation of the engine power with the altitude is given for most engines by the formula $P = P_o^{1.15}$, P_o being the power at sea level. The maximum power available and the minimum power required must be equal at the ceiling if the propeller is designed so as to give the best ceiling possible.

The horsepower curves at the ceiling with such a propeller would have a common horizontal tangent, as indi-

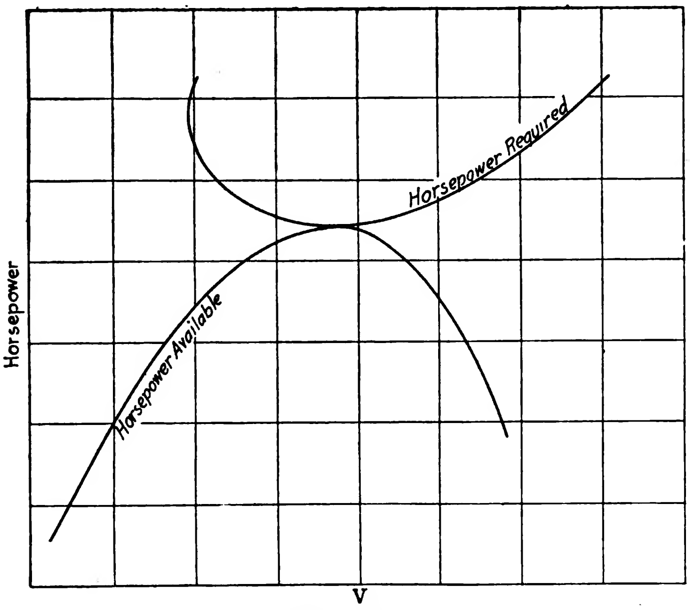


FIG. 6—HORSEPOWER CURVES AT THE CEILING

cated in Fig. 6. The condition of flight at the ceiling would then be expressed by the equation

$$P_{ro}(\rho_h/\rho_o)^{-0.5} = P_{ao}(\rho_h/\rho_o)^{1.15}$$

or

$$(\rho_o/\rho_h)^{1.65} = (P_{ao}/P_{ro})$$

where

ρ_h = the air density at the ceiling
ρ_o = the air density at sea level
P_{ro} = the minimum horsepower required at sea level
P_{ao} = the maximum horsepower available at sea level

Taking the logarithms of both sides of this equation we have

$$1.65 \log (\rho_o/\rho_h) = \log (P_{ao}/P_{ro})$$

The relation between the air density and the altitude under normal temperature-gradient conditions is given with sufficient exactness for most practical purposes by the formula

$$h = 69{,}000 \log_{10}(\rho_o/\rho_h)$$

Substituting in the power-density equation the value for the logarithm of the density ratio obtained from this density-altitude relation the formula for ceiling height becomes

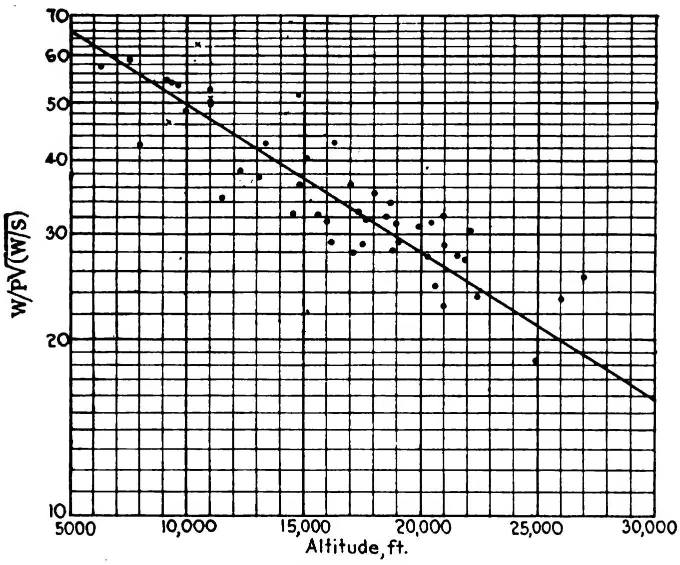


FIG. 7—APPLICATION OF THE FORMULA FOR CEILING TO A NUMBER OF AIRPLANES

$$H = 42{,}000 \log_{10}(P_{ao}/P_{ro})$$

Referring back to the approximate values given for P_{ao} and P_{ro}, however, it will be seen that their ratio is equal to $85.9 \div (W/P) \sqrt{(W/S)}$ and the theoretical formula for absolute ceiling in terms of the principal characteristics of the airplane therefore appears to be

$$H = 42{,}000 \log_{10} [85.9 \div (W/P) \sqrt{(W/S)}]$$

This formula, like the one for maximum speed, has been put to the test of application in a number of airplanes for which performance data were at hand, and the results are shown in Fig. 7. Semi-logarithmic paper was used in this instance in order that the formula just given might plot as a straight line. The points are so grouped as to leave no doubt that absolute ceiling is primarily a function of $(W/P)\sqrt{(W/S)}$, just as maximum speed has been seen to be primarily a function of P/S. The process of drawing the best average straight line through the points in Fig. 7, however, indicates that the ceiling formula, like that for maximum speed, can be improved by slight changes in the values of the constants, the changes in the present instance being very small. The actual form of the expression giving the best mean results for the 46 airplanes considered proves to be

$$H = 40{,}000 \log_{10} [87.6 \div (W/P) \sqrt{(W/S)}]$$

The average error in predicting the ceiling by this formula was 12.6 per cent. Absolute ceiling is both harder to calculate and harder to measnre than maximum speed, and it is therefore natural that the average error in the application of the formula should be somewhat larger for the ceiling than for the velocity.

If the time to climb to a particular altitude is required it can be found by calculating the absolute ceiling and the rate of climb at sea level and then applying the familiar climb formula

$$t = -(H/V_{co}) \cdot \log_e [1 - h/H)]$$

where

H = the absolute ceiling
t = the time to climb to the height h
V_{co} = the initial rate of climb

APPLICATIONS OF FORMULAS

In closing, it is of interest to consider a few examples showing how these formulas and curves can be applied to specific problems in the quick estimation of the approximate performance of an airplane. Suppose, for example, that it is required to design an airplane to have a maximum speed of 100 m.p.h. to carry 4000 lb. of useful load, including fuel, and to reach an absolute ceiling of at least 12,000 ft. The total weight, the power and the wing area are to be found. The requirement of a speed of 100 m.p.h. gives immediately a power-to-area ratio. By reference to Fig. 2, this is found to be 0.54. A similar reference to the ceiling chart, Fig. 7, shows that an absolute ceiling of 12,000 ft. requires that the value of $(W/P)\sqrt{(W/S)}$ shall not exceed 44. It is now possible to solve directly for the power loading and the wing loading, which are found to be 15.3 lb. per hp. and 8.3 lb. per sq. ft. Assuming the useful load to be 40 per cent of the total weight, the required quantities are found to be 10,000 lb., 655 hp. and 1210 sq. ft. The approximate minimum speed would be 40 m.p.h.

As a second illustration, we may find the minimum wing-area with which it will be possible to carry a total load of 4000 lb. to a height of 20,000 ft., using a 400-hp. engine. The power loading is then 10 lb. per hp., and Fig. 7 shows that $(W/P)\sqrt{(W/S)}$ must not exceed 27.7 if 20,000 ft. is to be reached. W/S therefore must be less than 7.7 lb. per sq. ft., and the wing area must be at least 520 sq. ft. The maximum speed should be 115 m.p.h. and the minimum, 47 m.p.h.

Reports of Divisions to Standards Committee

THE following Division Reports will be presented at the Standards Committee Meeting, Tuesday, June 20, beginning promptly at 10:30 a. m., at the White Hotel, White Sulphur Springs, W. Va. They are published in this issue of THE JOURNAL sufficiently in advance of the meeting to permit a careful review of the recommendations and the preparation of the discussion by the members of the Standards Committee and others.

The reports of the Divisions will be presented at the Standards Committee Meeting in the order in which they appear hereinafter. Discussion of the reports is invited from all who are technically familiar with the several subjects.

Under the Standards Committee Regulations only members of the Standards Committee may participate in the voting that will follow the discussion of each recommendation at the Standards Committee Meeting. At the Society Meeting only voting Members of the Society may participate in the voting.

All subjects passed at the Standards Committee and the Society Meetings will be reported in the August issue of THE JOURNAL and submitted to a letter ballot of all of the voting Members of the Society, unless contrary direction is given by the Council.

The several Divisions submitting reports, and the Subdivisions that in many instances prepared them, have considered carefully the respective subjects and the conditions bearing on them. It should be borne in mind that the recommendations, which have been founded on data obtained directly from the industries, are necessarily compromises in greater or less degree of the current practice of individual companies, and involve what may be considered ideal practice so far as this is feasible. It should be understood also that the recommendations need not necessarily be put into practice upon their adoption by the Society, but that they should be followed by the various industries when changes in design or production make it economically possible to do so.

The members of the Standards Committee, who are selected because of their broad experience and ability to represent adequately the many branches of the automotive industries, have given generously of their time and resources to the standardization work during the past months in face of their more or less increased regular duties. The standardization work involved traveling to and attending 24 Division meetings and a dozen or more Subdivision meetings.

This truly indicates the recognized value of standards, and makes it practically necessary for the managers and executive directors of the industries to keep informed of the work being done by the Society, and to give it due recognition and support by having the standards used in their products as extensively as possible. The manufacturing and sales executives are urged to review the recommendations of the Standards Committee, to bring their points of view to bear in the discussion at the White Sulphur sessions and to facilitate the work of the engineers in the production of the products involved by having the standard recommendations reduced to practice as promptly and widely as is feasible.

PROGRESS REPORTS

Arrangements have been made with some of the Chairmen of Divisions and Subdivisions for presenting progress reports on a few of the more important subjects that are under consideration but are not ready for final recommendation to the Standards Committee. These reports are intended primarily to familiarize the Standards Committee members in a general way with what is being accomplished and to give the Divisions or Subdivisions the benefit of discussion by the Standards Committee and its guests as a guide in further study of the subjects.

The subjects on which it is planned to have progress discussion are listed below. The progress report of the Lubricants Division is appended to the Division reports.

Crankcase Lubricants
  H. C. Mougey, chairman Lubricants Division
Engine and Frame Numbers
  R. S. Begg, chairman Passenger-Car Division
  J. B. Fisher, chairman Engine Division
Metric Thrust Ball-Bearings
  E. N. Carter, member Subdivision
Brake-Linings
  Clarence Carson, chairman Subdivision
Automotive Starting and Lighting Equipment
  A. D. T. Libby, member Electrical Equipment Division

The presentation of the last-named subject in the foregoing list at the Standards Committee meeting is planned in order to discuss the work that has been done in the standardization of automotive starting and lighting equipment and the actual use of the standards by engine and automobile manufacturers. Mr. Libby is well posted on the work of the Electrical Equipment Division and other bodies interested in the subject, which has resulted in the standards adopted by the Society and printed on pages B17 to B20 inclusive of the S.A.E. HANDBOOK.

AXLE AND WHEELS DIVISION REPORT

Division Personnel

G. W. Dunham, *Chairman*	Savage Arms Corporation
C. C. Carlton, *Vice-Chairman*	Motor Wheel Corporation
R. S. Begg	Jordan Motor Car Co.
T. V. Buckwalter	Timken Roller Bearing Co.
A. C. Burch	Formerly with Clydesdale Motor Truck Co.
R. J. Burrows	Clark Equipment Co.
L. W. Close	Bock Bearing Co.
J. Coapman	Russel Motor Axle Co.
C. S. Dahlquist	Eaton Axle Co.
F. S. Denneen	Grant Motor Car Co.
F. W. Gurney	Gurney Ball Bearing Co.
F. P. Hall, Jr.	Salisbury Axle Co.
G. W. Harper	Columbia Axle Co.
G. L. Lavery	West Steel Casting Co.
A. M. Laycock	Sheldon Axle & Spring Co.
H. V. Ludwick	Budd Wheel Corporation
C. T. Myers	Consulting Engineer
A. L. Putnam	Detroit Pressed Steel Co.
O. J. Rohde	Wire Wheel Corporation of America
H. Vanderbeek	Timken-Detroit Axle Co.

Motor-Truck Front-Axle Hubs

(*Proposed Extension of S.A.E. Recommended Practice*)

When the present S.A.E. Recommended Practice for Motor-Truck Front-Axle Hubs, page F1b of the S.A.E. Handbook, was reported to the Standards Committee in January 1921, the report contained many detail dimensions that were not included in the recommended practice finally adopted in July.

In January 1922 a new Division of the Standards Committee, known as the Axle and Wheels Division, was appointed to consider all matters pertaining to axle and wheel assemblies. Among the subjects assigned to this Division is Passenger-Car Front-Axle Hubs, a recommendation for which is now being formulated by a Subdivision, which has practically the same personnel as the Subdivision of the Truck Division that formulated the Report on Motor-Truck Front-Axle Hubs. At a meeting of this Subdivision in April it was recommended that the complete dimensions for the threaded end of the spindle for motor-truck front-axle hubs, that were shown in the original report last year, should be incorporated in the present S.A.E. Recommended Practice to provide a complete standard for motor-truck front-axle spindles. It was also recommended that a supplementary table, to be used as general information only, be appended to the recommended practice to indicate the fundamental factors upon which the report was based. These recommendations were approved by the members of the Axle and Wheels Division by letter ballot. Therefore

> The Axle and Wheels Division recommends that the accompanying tables be approved by the Standards Committee for adoption as an extension of the present S.A.E. Recommended Practice for Motor-Truck Front-Axle Hubs, page F1b of the S.A.E. Handbook

DIMENSIONS OF MOTOR-TRUCK FRONT-AXLE SPINDLE-ENDS

Spindle No.	5	6	7	8	9
Thread, U. S. S....	1⅛–7	1⅛–7	1½–6	1½–6	1½–6
Length of threaded end.........	$1\frac{9}{16}$	$1\frac{9}{16}$	$1\frac{13}{16}$	$1\frac{13}{16}$	$1\frac{13}{16}$
Height from center-line of spindle to flat milled on threaded-end ...	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$
Center of cotter-pin hole to end of thread.......	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$
Diam. of cotter-pin hole........	$\frac{7}{32}$	$\frac{7}{32}$	$\frac{7}{32}$	$\frac{7}{32}$	$\frac{7}{32}$
Width of groove at back end of thread.........	⅛	⅛	⅛	⅛	⅛

GENERAL INFORMATION FOR MOTOR-TRUCK FRONT-AXLE HUBS

Spindle No.	5	6	7	8	9
Spindle load rating in Lb. on solid tire at ground	1250	1625	2125	2750	3500
Solid tire size	34x3½	36x4	36x5	36x6	36x7
Solid tire load rating, Lb.	1300	1700	2500	3300	4200

ELECTRICAL EQUIPMENT DIVISION REPORT

Division Personnel

F. W. Andrew, *Chairman*	Eisemann Magneto Corporation
T. L. Lee, *Vice Chairman*	North East Electric Co.
Azel Ames	Kerite Insulated Wire & Cable Co.
G. S. Cawthorne	Master Trucks, Inc.
W. A. Chryst	Dayton Engineering Laboratories Co.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Corporation
W. S. Haggott	Packard Electric Co.
C. H. Kindl	Westinghouse Electric & Mfg. Co.
F. C. Kroeger	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
A. D. T. Libby	Splitdorf Electrical Co.
Charles Marcus	Bijur Motor Appliance Co.
Ernest Wooler	Cleveland Automobile Co.

Ignition-Distributor Mountings

(*Proposed Revision of S.A.E. Standard*)

The present S.A.E. Standard for Ignition-Distributor Mountings, page B16 of the S.A.E. Handbook, specifies that the distance from the base of the distributor mounting barrel to the bottom of the tongue of the distributor half of the driving coupling shall "vary to suit conditions." As it was suggested by an ignition-distributor manufacturer that this dimension should be definitely established, W. A. Chryst, of the Dayton Engineering Laboratories Co., was appointed a Subdivision to report on the advisability of this.

Mr. Chryst submitted at the April meeting of the Electrical Equipment Division a report which was approved.

This report was referred to automobile engine and ignition-apparatus manufacturers for comment and met with general approval. Therefore

> The Division recommends that the present S.A.E. Standard for Ignition-Distributor Mountings be revised by
>
> (1) Specifying a dimension of 27/32 in. for the distance from the bottom of the distributor mounting barrel to the bottom of the tongue on the distributor half of the driving coupling of the Type-B ignition-distributor
>
> (2) Changing the limits for the bore in the coupling from 0.4930 in. maximum and 0.4920 in. minimum to 0.4915 in. maximum and 0.4905 in. minimum

Magneto Mountings

(*Proposed S.A.E. Standard*)

Several requests were received by the Society in 1920 for the standardization of mountings for magnetos used on stationary engines, isolated electric-lighting plants and small tractors on which the present S.A.E. Standard magneto mounting could not be used. In view of the importance of such standardization, the following Subdivision of the Electrical Equipment Division was appointed:

F. W. Andrew, *Chairman*	Eisemann Magneto Corporation
W. F. Borgerd	International Harvester Co.
James M. Edwards	Associated Manufacturers Co.
A. D. T. Libby	Splitdorf Electrical Co.
F. L. Tubbs	Alamo Farm Light Co.

As the three members last named are members of the Agricultural Power Equipment, Stationary-Engine and the Isolated Electric Lighting Plant Divisions, respectively, the Subdivision was representative of all interests involved.

Upon making a general survey of the situation, the Subdivision found that the practice varied considerably,

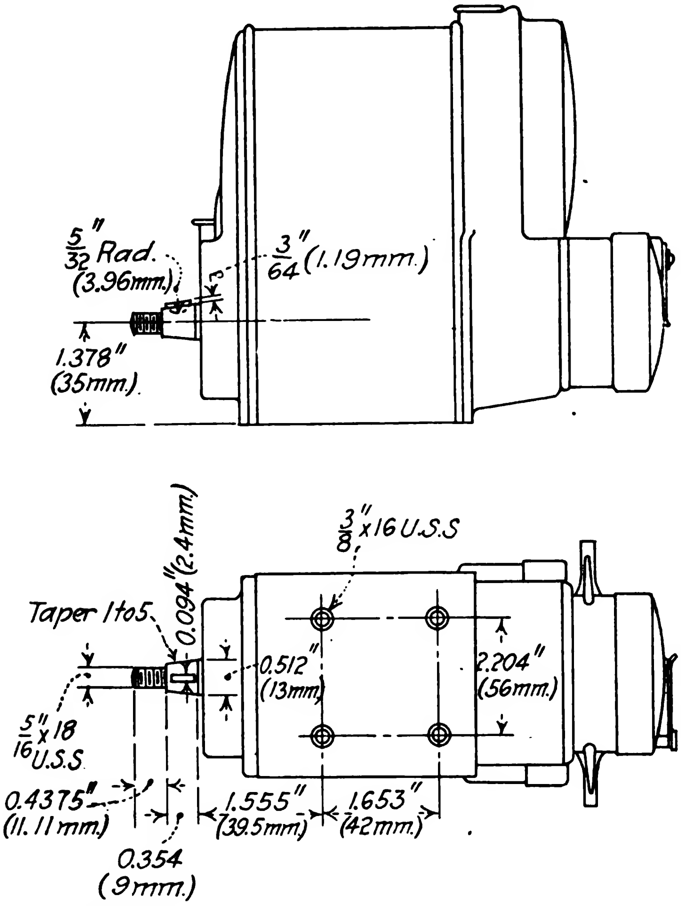
comparatively few companies using the same dimensions for mounting small magnetos.

A meeting of members of the Subdivision and a number of others was held on Nov. 3, 1921, following a two-day session of the Gas Engine and Farm Power Association at which most of the magneto manufacturers were represented. As a result of this conference a Subdivision report was formulated and sent to stationary-engine, isolated electric-lighting plant, tractor and magneto manufacturers for comment. A large number of replies were received indicating general approval of the report.

The recommendation was also published in the April issue of THE JOURNAL.

At the meeting of the Electrical Equipment Division on April 14, Mr. Andrews submitted the report of the Subdivision which was carefully discussed. It was thought, however, advisable to extend the report to include the timing-lever dimensions in accordance with the dimensions specified in the present standard for motorcycle magnetos. Therefore

> The Division recommends that the magneto dimensions given in the accompanying illustration be adopted as S.A.E. Recommended Practice, as an addition to the present S.A.E. Standard for Magneto Mountings, page B14 of the S.A.E. HANDBOOK



Timing-lever plain-hole diameter: 0.2185 in. (5.55 mm.)
Advance-lever radius: 1.9680 in. (50 mm.)

BREAKER-CONTACTS

(Proposed S.A.E. Recommended Practice)

At the October 1921 meeting of the Electrical Equipment Division it was suggested by a Division member that a standard for breaker-contact nuts would overcome the necessity for service-stations carrying several sizes of wrenches in stock to fit the different makes of breaker-contact points.

As the importance of attaining such standardization in practice was appreciated, information was obtained from ignition-apparatus manufacturers as to their current practice. A careful analysis of the information obtained was made at a meeting of the Division in April which indicated that only the distance across the flats of the hexagon-head and the size and pitch of the thread should be standardized, as it was not intended to provide in the standard for complete interchangeability of breaker-contacts of different makes. Therefore

> The Electrical Equipment Division recommends for S.A.E. Recommended Practice that the hexagon-head of breaker-contacts and check-nuts shall be ¼ in. across flats and that the threads shall be No. 10-40 or No. 8-40

STARTING-MOTOR FLANGE MOUNTINGS

(Proposed Revision of S.A.E. Standard)

The Electrical Equipment Division recommended at the Standards Committee meeting in January 1922 that the bolt-hole diameters for the Nos. 1 and 2 mountings specified in the S.A.E. Standard for Starting-Motor Flange Mountings, page B19 of the S.A.E. HANDBOOK, be changed from 13/32 to 7/16 in. This revision was approved and adopted by the Society in March.

Several negative letter-ballots were cast by Society Members against this change. The reasons given in support of the negative votes were referred to and carefully considered by the Subdivision on Generator and Starting-Motor Mountings.

At the meeting of the Electrical Equipment Division in April the Subdivision reported that, after an investigation of the reasons for making the change in the standard last March, it felt that an error had been made in adopting the 7/16-in. hole diameter. Therefore

> The Electrical Equipment Division recommends that dimension "C," the diameter of the bolt-holes for sizes Nos. 1 and 2 of the S.A.E. Standard for Starting-Motor Flange Mountings, page B19 of the S.A.E. HANDBOOK, be changed from 7/16 to 13/32 in.

AGRICULTURAL POWER EQUIPMENT DIVISION

Division Personnel

John Mainland, *Chairman*	Advance-Rumely Co.
C. B. Rose, *Vice-Chairman*	Moline Plow Co.
D. L. Arnold	International Harvester Co.
J. B. Bartholomew	Avery Co.
J. H. Davis	General Motors Research Corporation
C. E. Frudden	Hart-Parr Co.
A. H. Gilbert	Rock Island Plow Co.
R. O. Hendrickson	J. I. Case Plow Works Co.
M. B. Morgan	Cleveland Tractor Co.
A. W. Scarratt	Minneapolis Steel & Machinery Co.
O. W. Sjogren	University of Nebraska
William Turnbull	Holt Mfg. Co.
L. W. Witry	Waterloo Gasoline Engine Co.
G. A. Young	Purdue University
O. W. Young	Hyatt Roller Bearing Co.

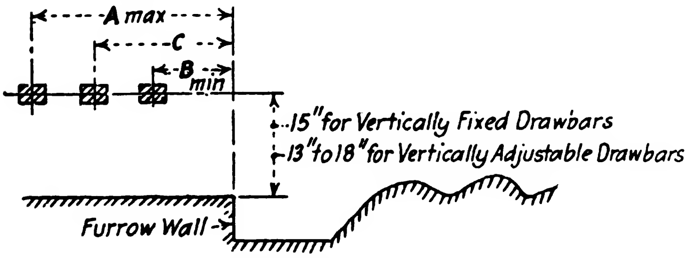
TRACTOR DRAWBAR ADJUSTMENTS

(Proposed Revision of S.A.E. Standard)

Since the adoption of the last revision of the S.A.E. Standard for Tractor Drawbar Adjustments, page K40 of the S.A.E. HANDBOOK, O. B. Zimmerman of the International Harvester Co., who has been serving as a Subdivision, carried out further tests with the result that he recommended some slight changes in the present standard at a meeting of the Agricultural Power Equipment Division in April. Other members of the Division reported that, although the results of similar tests carried

out by them did not exactly agree with Mr. Zimmerman's, they were within the limits given in the proposed revision. Therefore

> The Agricultural Power Equipment Division recommends that the present S.A.E. Standard for Tractor Drawbar Adjustments, page K40 of the S.A.E. HANDBOOK, be revised to conform with the limits specified in the accompanying table



TRACTOR DRAWBAR ADJUSTMENTS

PLOW	TWO-BOTTOM		THREE-BOTTOM		FOUR-BOTTOM	
	12-In.	14-In.	12-In.	14-In.	12-In.	14-In.
A Max.	30	30	30	32	35	40
B Min.	13	15	18	20	22	24
C Best Average	17	20	22	26	27	32

A—Maximum hitching position from the furrow wall, very often necessary when the tractor operates on the land

B—Minimum hitching position from the furrow wall when the tractor operates in the furrow

C—Best average hitching position from the furrow wall

ENGINE DIVISION REPORT

Division Personnel

J. B. Fisher, *Chairman*	Waukesha Motor Co.
R. J. Broege, *Vice-Chairman*	Buda Co.
P. J. Dasey	Midwest Engine Co.
S. F. Evelyn	Continental Motors Corporation
E. J. Hall	Hall-Scott Motor Co.
H. B. Massey	Holmes Automobile Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Louis Schwitzer	Automotive Parts Co.
M. J. Steele	Packard Motor Car Co.
William Turnbull	Holt Mfg. Co.

CRANKCASE DRAIN-PLUGS

(Proposed S.A.E. Recommended Practice)

The advisability of designing engines with a conveniently located oil-pan drain that would permit draining the oil from the crankcase as easily as it is poured into it was brought to the attention of the Society in the fall of 1921. The subject was referred to the Engine Division for consideration.

Information was obtained from engine and automobile builders who build their own engines as to their methods of draining crankcases. Suggestions were submitted by an oil company that had conducted an investigation of the subject which resulted in a large number of suggestions from engineers.

Data obtained as to the size of the oil-drain hole and the location and means of operating the drain-plug were analyzed carefully at a meeting of the Engine Division in April. It was not considered feasible to standardize upon a definite means of operating the drain-plug or the design of the oil drain. The following recommendation was considered, however, to be in accord with good engineering practice. Therefore

> The Engine Division recommends for S.A.E. Recommended Practice that crankcase drain-plugs shall have a minimum opening of ¾ in., be located at the lowest point of the oil-pan and be operable from under the engine hood

FLYWHEEL HOUSINGS

(Proposed Revision of S.A.E. Standard)

The present S.A.E. Standard for Flywheel Housings, page A1 of the S.A.E. HANDBOOK, was revised in July 1921 to specify that

> The minimum diameter of the clearance space for crankshaft flywheel bolts shall be 6⅛ in. and the minimum depth ⅝ in.

At the September 1921 meeting of the Division this revision was discussed and the point brought out that the clearance space allowed would not be satisfactory for two-bearing engines having a large crankshaft flange. It was thought that the present clearances would not permit the use of ½-in. U. S. Standard bolts and nuts or S.A.E. Standard bolts and nuts with cotter-pins. Furthermore, it was considered that a larger clearance space should be recommended to allow for possible wear in the clutch. The revision indicated was favorably considered at the meeting of the Division in April 1922. Therefore

> The Engine Division recommends that the present S.A.E. Standard for Flywheel Housings, page A1 of the S.A.E. HANDBOOK, be revised to specify that the clearance space for crankshaft flywheel bolts shall be 6½-in. minimum diameter and ¾-in. minimum depth

MOTORCYCLE CARBURETER FLANGES

(Proposed S.A.E. Recommended Practice)

The possibility of standardizing motorcycle carbureter flanges was suggested by the Motorcycle Division in 1920. It was thought that, although practice varied to a large extent, a standard could be established, and the subject was referred to the Engine Division. A subdivision was appointed that conducted a rather extensive investigation among the carbureter and motorcycle manufacturers. The members of the Subdivision were:

R. J. Broege, *Chairman*	Buda Co.
E. H. Shepard	Stromberg Motor Devices Co.
V. I. Shobe	Zenith Carbureter Co.
W. G. Clark	Wilcox-Bennett Carbureter Co.
C. B. Franklin	
Hendee Mfg. Co.	

A report was formulated which met with the general approval of the carbureter and motorcycle manufacturers, and was reviewed and approved at the April meeting of the Division. Therefore

> The Engine Division recommends that the dimensions specified in the accompanying tables for Motorcycle Carbureter Flanges be added to the present S.A.E. Recommended Practice for Carbureter Flanges, page A8 of the S.A.E. HANDBOOK

The proposed two-bolt type flanges for motorcycle carbureters conform with the present standard two-bolt type flanges. The three-bolt flanges have been proportioned so that all nominal carbureter sizes of this type can be made from but two castings.

IRON AND STEEL DIVISION REPORT

Division Personnel

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corporation
W. C. Peterson, *Vice-Chairman*	Electric Alloy Steel Co.

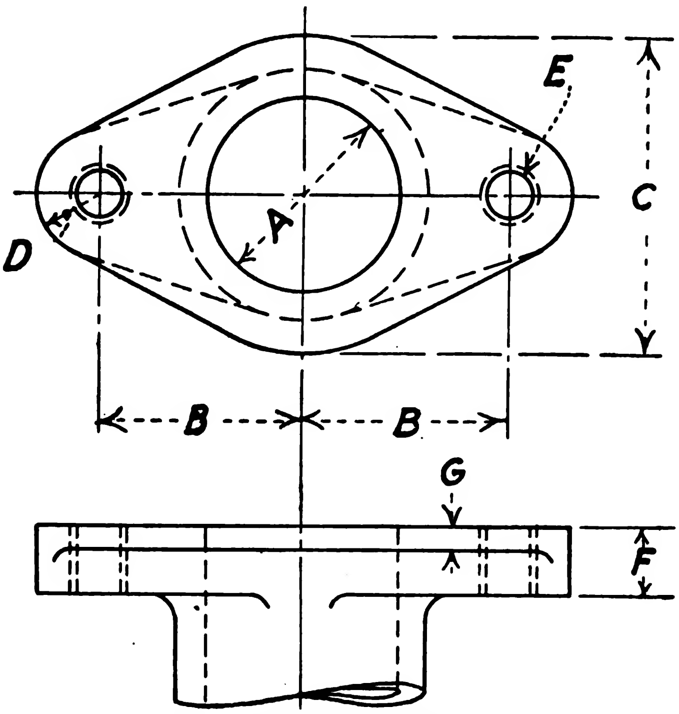


FIG. 1—¾ AND ⅞-IN. NOMINAL SIZE

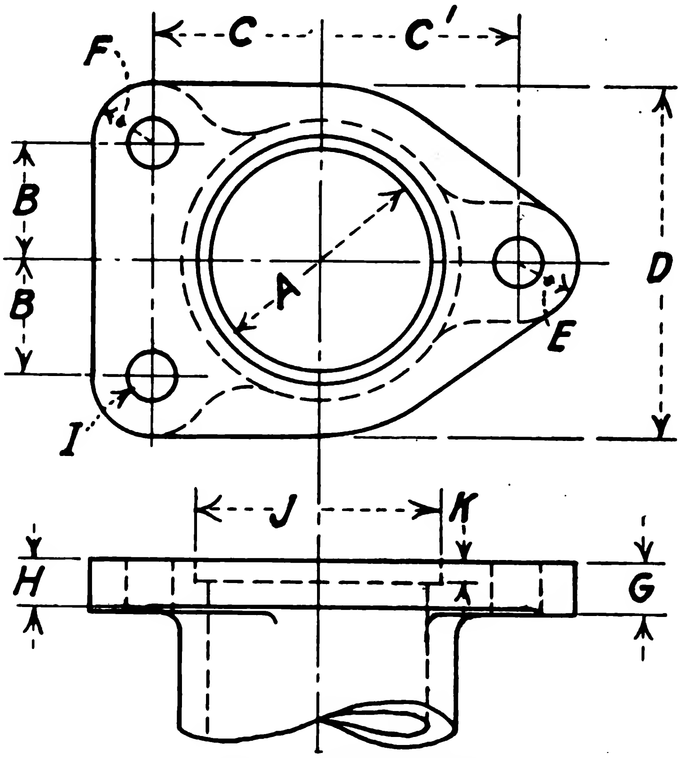


FIG. 2—1-IN. NOMINAL SIZE

R. M. Bird	Bethlehem Steel Co.
H. T. Chandler	C. H. Wills & Co.
A. L. Colby	Consulting Metallurgist
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
A. P. Eves	International Harvester Co.
E. L. French	Crucible Steel Co. of America
H. L. Greene	Willys-Overland Co.
C. G. Heilman	General Motors Corporation
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Ordnance Department
A. H. Miller	Midvale Steel & Ordnance Co.
C. S. Moody	Minneapolis Steel & Machinery Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
W. H. Phillips	R. D. Nuttall Co.
S. P. Rockwell	Consulting Metallurgist
M. P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carengie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
H. J. Stagg	Halcomb Steel Co.
J. M. Watson	Hupp Motor Car Corporation
J. H. G. Williams	Billings & Spencer

LEAF-SPRING STEEL

(Proposed S.A.E. Recommended Practice)

In 1921 the leaf-spring manufacturers, acting through the Motor & Accessory Manufacturers Association, submitted for approval by the Society a proposed specification for rolling tolerances for automobile leaf-spring steel. The specification had been prepared and approved by steel and leaf-spring manufacturers in view of the need for uniformity in rolling leaf-springs.

The subject was assigned to the Iron and Steel Division and considered at a meeting in January 1922. The proposed specification was then circulated, with favorable results, among steel mills, automobile and spring manufacturers, and also referred to the Springs Division,

which approved it. It was published in the April issue of THE JOURNAL.

Copies of all comments received as a result of this publicity were referred to the members of the Iron and Steel Division, who have indicated by letter ballot their approval of the recommendation as originally submitted to the Society. Therefore

The Iron and Steel Division recommends the adoption of the accompanying specification for leaf-spring steel tolerances as S.A.E. Recommended Practice

ROLLING TOLERANCES FOR CONCAVE AUTOMOBILE SPRING STEEL

The finished bars shall be of double-concave section with round edges. The radii of the arcs of the two concave surfaces shall be of equal length

Rolls to produce the round edges shall be turned to a radius equal to two-thirds the thickness of the bar

All bars ordered to gage shall be rolled to the Birmingham wire gage

All bars must meet the width and thickness tolerances specified in the following table

WIDTH AND THICKNESS TOLERANCES

Width of Flat, in. Over	To, Inclusive	Width, in. Plus	Width, in. Minus	Thickness,[1] in. Plus	Thickness,[1] in. Minus
0	2¼	1/32	0	0.005	0.005
2¼	3	3/64	0	0.006	0.006
3	5	1/16	0	0.007	0.007

[1] Thickness measurement to be taken at edge of bar where concave surface intersects round edge.

The difference in thickness between the two edges of each bar shall not be greater than those given in the following table

DIFFERENCES IN THICKNESS

Width of Flat, in. Over	To, Inclusive	Difference in Thickness, in.
0	2	0.002
2	3	0.003
3	5	0.004

Spring-steel bars shall not have more than 1-in. curvature in 20 ft., or 1¼ in. in 25 ft., or 1½ in. in 30 ft.

The concavity, or difference between the thickness at the edges and at the center of the bar, shall be as specified in the following table

ALLOWABLE VARIATIONS IN CONCAVITY

Width, in.	Nominal Concavity, in.	Maximum Concavity, in.	Minimum Concavity, in.
1½	0.007	0.009	0.004
1¾	0.008	0.010	0.005
2	0.010	0.012	0.006
2¼	0.011	0.013	0.007
2½	0.013	0.015	0.009
3	0.016	0.018	0.012
3½	0.018	0.020	0.013
4	0.021	0.023	0.016
5	0.029	0.031	0.023

STEEL SPRING-WIRE

(*Proposed S.A.E. Standard*)

At the time of the Society letter-ballot on the adoption of standards approved at the Standards Committee Meeting in January 1922, an objection was made that the chemical specification for carbon steel did not provide proper compositions for drawn spring-wire. This objection was considered at a meeting of the Division in February 1922. Although the specifications formulated by the Iron and Steel Division so far have included primarily steel compositions for forging purposes only, it was felt that chemical compositions might well be adopted for spring steel-wire. A representative Subdivision was appointed, the members of which were:

L. A. Danse, *Chairman*	Cadillac Motor Car Co.
W. C. Peterson	Atlas Crucible Steel Co.
E. W. Stewart	William B. Gibson Co.
F. C. Elder	American Steel & Wire Co.
H. S. Durant	American Steel & Wire Co.

The Subdivision held a meeting on April 10 at which a recommendation was approved, and this was submitted to and approved by the Division. Copies of the recommendation were sent to automobile and spring manufacturers for comment, the result being favorable in general. Some suggestions were received to the effect that suitable specifications should be adopted for poppet-valve spring-wire made of other than carbon steels, such as chrome-vanadium, which would withstand fatigue in high-duty service. These suggestions have been referred to the Iron and Steel Division. Therefore

The Division recommends that the chemical compositions given in the accompanying table be adopted as S.A.E. Standard for round, cold-drawn wire up to 3/16-in. diameter, except for some types of springs used in clutches, which are hot-rolled

STEEL WIRE FOR HELICAL SPRINGS

S.A.E. Steel No.	Wire Diameters, In.[2]	Carbon	Manganese	Phosphorus Max.	Sulphur Max.	Silicon Max.
1350	0.025 to 0.100	0.45–0.55	0.90–1.20	0.04	0.05	0.30
1360	0.100 and larger	0.55–0.70	0.90–1.20	0.04	0.05	0.30

[2] Approximately.

LIGHTING DIVISION REPORT

Division Personnel

W. A. McKay, *Chairman*	Westinghouse Lamp Co.
C. A. Michel, *Vice-Chairman*	Guide Motor Lamp Mfg. Co.
J. T. Caldwell	National Lamp Works
C. E. Godley	Edmunds & Jones Corporation
C. A. B. Halvorson, Jr.	General Electric Co.
L. C. Porter	Edison Lamp Works
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Corcoran-Victor Co.
C. H. Sharp	Electrical Testing Laboratories
J. C. Stearns	Culver-Stearns Mfg. Co.
T. I. Walker	Providence Base Works
E. E. Wood	Miniature Incandescent Lamp Corporation
Ernest Wooler	Cleveland Automobile Co.

HEAD-LAMPS

(*Proposed Revision of S.A.E. Recommended Practice*)

The present S.A.E. Recommended Practice on page B1 of the S.A.E. HANDBOOK is not considered to be entirely clear in the paragraph under the sub-heading "Mounting." It is also felt by the Division that specific mention should be made in this specification of adjustable types of mounting bracket on radiator shells, tie-rods and the like. Therefore

The Lighting Division recommends that the present S.A.E. Recommended Practice for Head-lamps, page B1 of the S.A.E. HANDBOOK, be revised as indicated below

(1) Change the second sentence in the paragraph under the subheading "Mounting," which

now reads. "Means for adjusting the head-lamps shall be provided so as to permit a change in the vertical as well as in the horizontal angle of the head-lamps, * * *" to read "For adjustable types of head-lamp mountings means shall be provided, * * *"

(2) Under the sub-heading "Brackets" insert the following: "*Adjustable Type*.—The adjustable type of mounting-bracket for head-lamps mounted on fenders, radiator shells, frame-pillars, tie-rods and similar constructions, as shown on page B1a of the S.A.E. HANDBOOK, is recommended"

ELECTRIC INCANDESCENT LAMPS

(Proposed Revision of S.A.E. Standard)

At the meeting of the Lighting Division held on May 3 information was received indicating that the G10, G12 and G16½ sizes of focusing type electric incandescent lamp have practically been discontinued in use. It was the opinion that the present S.A.E. Standard on page B3 of the S.A.E. HANDBOOK should be revised by cancelling these lamp sizes. Therefore

The Lighting Division recommends that the G10, G12 and G16½ lamps be omitted from the S.A.E. Standard for Electric Incandescent Lamps, page B3 of the S.A.E. HANDBOOK

ELECTRIC INCANDESCENT LAMP VOLTAGE

(Proposed Revision of S.A.E. Standard)

In connection with the present S.A.E. Standard on page B1c of the S.A.E. HANDBOOK, which specifies four voltage-ranges, namely 6 to 8, 8 to 10, 12 to 16, and 18 to 24, for automotive starting and lighting equipment, it is understood that 8 to 10 and 18 to 24-volt lighting equipment has been discontinued by the manufacturers and that all substantially standard equipment is now being made for 6 to 8 and 12 to 16 voltage-ranges. Therefore

The Lighting Division recommends that the present S.A.E. Standard for Electric Incandescent Lamp Voltages be revised by omitting the 8 to 10 and the 18 to 24 voltage-ranges and the reference to four and nine battery-cell arrangements

MOTORBOAT LIGHTING VOLTAGES

(Proposed S.A.E. Recommended Practice)

At the meeting of the Motorboat Division held in New York City on April 10 it was suggested that standard voltages be adopted for lighting equipment on motorboats, inasmuch as there is no well-defined practice in this connection.

The discussion indicated that two systems are used for lighting motorboats; (*a*) combined starting and lighting apparatus and (*b*) separate lighting units. It was felt that 12 volts would be most suitable for the combined systems, to make standard automobile types of starting and lighting apparatus available, the 6-volt system being too low in voltage for the usual comparatively long lighting circuits.

It was pointed out that the usual practice for lighting the larger motorboats is to install separate lighting equipment, and that the best voltages are already standard for isolated electric-lighting plants and the many electric lamps, fittings and fixtures operated with them.

The subject was referred to the Motorboat Lighting Equipment Subdivision of the Lighting Division, which reported to the Lighting Division on May 3. The report covered a nominal 6-volt combined starting and lighting system for use in the smaller types of motorboat, where the length of the circuits is relatively short. The 64-volt system was excluded as its use is decreasing, especially in railroad-car lighting systems where it is used most generally. Sixty-four-volt lamps and other types of fixture also are being discontinued. Therefore

The Lighting Division recommends that the accompanying report submitted by the Subdivision be adopted as S.A.E. Recommended Practice.

(1) For motorboats and small cruisers having combined starting and lighting equipment, it is recommended that nominal 6-volt (6 to 8 volts) or nominal 12-volt (12 to 16 volts) systems be used

(2) For larger cruisers having separate lighting equipment, it is recommended that the 32 or 110-volt system be used

NON-FERROUS METALS DIVISION REPORT

Division Personnel

Charles Pack, *Chairman*	Doehler Die-Casting Co.
W. B. Price, *Vice-Chairman*	Scovill Mfg. Co.
W. H. Bassett	American Brass Co.
A. G. Carman	Franklin Die-Casting Corporation
D. L. Colwell	Stewart Mfg. Co.
G. K. Elliott	Lunkenheimer Co.
J. R. Freeman, Jr.	Bureau of Standards
E. S. Fretz	Light Mfg. & Foundry Co.
A. J. Hall	General Motors Corporation
Zay Jeffries	Aluminum Manufacturers, Inc.
H. C. Mougey	General Motors Research Corporation
G. C. Rauhauser	Denby Motor Truck Co.
J. F. Thompson	International Nickel Co.
Samuel Tour	Doehler Die-Casting Co.
W. R. Webster	Bridgeport Brass Co.

ALUMINUM ALLOYS

(Proposed S.A.E. Standard)

In 1921 the Society received a request that a specification be formulated for an aluminum alloy with a copper-content of about 10 per cent, commonly used for pistons. This request was referred to Zay Jeffries, of the Aluminum Manufactures, Inc., who is chairman of the Subdivision on Aluminum Alloys. The members of the Subdivision are

Zay Jeffries, *Chairman*	Aluminum Manufactures, Inc.
E. Blough	Aluminum Manufactures, Inc.
E. S. Fretz	Light Mfg. & Foundry Co.

At the May 1922 meeting of the Division, the Subdivision submitted a specification which was approved by the Division. Therefore

The Non-Ferrous Metals Division recommends that Specification No. 34 be adopted as S.A.E. Standard

SPECIFICATION NO. 34, ALUMINUM ALLOYS

Composition in percentage:

Aluminum, min.	87.00
Copper	9.25 to 10.75
Iron	0.90 to 1.50
Magnesium	0.15 to 0.35
All other elements, not over	0.75

General Information.—Test-bars cast in a chill mold show a tensile-strength of 24,000 to 30,000 lb. per sq. in. and the elongation in 2 in. is usually less than 1 per cent. The specific gravity should not exceed 2.95. The Brinell hardness number, using a 500 or 1000-kg. load with a ball 10 mm. in diameter, should be not less than 85 and should average about 105.

This alloy cast in permanent molds is used principally for pistons, camshaft bearings, valve tappet guides and other parts where high hardness and good bearing qualities are essential.

WROUGHT NON-FERROUS ALLOYS

(Proposed S.A.E. Standard)

Since the last Non-Ferrous Metals Division report was approved by the Society, the Subdivision on Wrought Non-Ferrous Alloys has formulated additional specifications for wrought alloys used extensively in the automotive industry. The members of this Subdivision are

W. B. Price, *Chairman*	Scovill Mfg. Co.
H. C. Mougey	General Motors Research Corporation
W. H. Bassett	American Brass Co.
William R. Webster	Bridgeport Brass Co.

Three specifications were prepared and submitted by the Subdivision, (*a*) Phosphor-Bronze Strips for Flat Springs, (*b*) Brass Wire for Brazing and (*c*) Soft or Annealed Copper Wire. The Non-Ferrous Metals Division at its meeting on May 1 approved these specifications.

At the meeting of the Division on May 1 the Subdivision on Aluminum Alloys submitted a specification for aluminum sheet, closely conforming to Specification No. B-25-19T, of the American Society for Testing Materials, for adoption as S.A.E. Specification No. 78. This specification was approved by the Division. Therefore

The Non-Ferrous Metals Division recommends that Specifications Nos. 77, 78, 82 and 83 be adopted as S.A.E. Standard

SPECIFICATION NO. 77, PHOSPHOR BRONZE STRIP FOR FLAT SPRINGS

This specification covers bronze strips up to 0.080 in. gage for flat springs and includes a variety of tempers in two alloys, from which a suitable quality can be chosen for any ordinary purpose.

Composition in percentage:

	Grade A	Grade B
Tin	4.00 to 6.00	7.00 to 9.00
Phosphorus	0.03 to 0.40	0.03 to 0.20
Zinc, max.	0.20	0.20
Iron, max.	0.10	0.10
Lead, max.	0.10	0.10
Copper	Remainder	Remainder

Temper Designation.—The temper of strip phosphor bronze shall be designated as follows:

Temper	Reduction, B. & S., Nos.
Half Hard	2
Hard	4
Extra Hard	6
Spring	8

Physical Properties.—The average tension test of two samples of sheet thinner than 0.080 in. should conform to the minimum requirements specified in the accompanying table.

In very thin strips, on account of difficulties in testing, the elongation may be considerably less than the values given.

MINIMUM PHYSICAL PROPERTIES

Temper	GRADE A		GRADE B	
	Minimum Tensile-Strength, Lb. Per Sq. In.	Minimum Elongation in 2 In., Per Cent	Minimum Tensile-Strength, Lb. Per Sq. In.	Minimum Elongation in 2 In., Per Cent
Half Hard	55,000	15.0	65,000	20.0
Hard	75,000	5.0	85,000	7.5
Extra Hard	85,000	2.0	100,000	1.0
Spring	90,000	1.0	......	....

Dimensional Tolerances.—The width of the strip shall not vary more than 0.01 in. from the size specified in the order.

General Information.—These should be considered as general specifications. Phosphor bronze strip is used for various kinds of springs where the manufacturing requirements and the uses to which the springs are put are too particular to be specified by ordinary physical tests. It is advisable to submit samples or drawings to the manufacture and secure an adjustment of temper to suit the manufacturing and service requirements of the article.

Flat springs formed with easy bends across the grain are usually made of the Grade A alloy, "Spring" temper.

Flat springs with easy bends either across or with the grain are usually made of the Grade B alloy, "Extra Hard" temper.

Clips or contact springs with most difficult bends are usually made of the Grade B alloy, "Hard" temper.

SPECIFICATION NO. 78, ALUMINUM SHEET AND STRIP

Composition in percentage:

Aluminum, min. 99.00

Physical Properties.—Aluminum sheet and strip are furnished in several tempers or degrees of hardness. The mechanical properties of aluminum sheet or strip conforming to Tempers, No. 1, Soft Annealed; No. 2, Half-Hard, and No. 3, Hard, are given in Table 1.

The tension test-specimen is taken parallel to the direction of cold-rolling. Sheet or strip of Temper No. 1 should withstand being bent double in any direction and hammered flat. Sheet or strip of Temper No. 2 should withstand being bent around a pin of radius equal to the thickness of the sheet,

THICKNESS TOLERANCES

Thickness				Width, In.			
B. & S. Gage No.		Decimal		Up to 5 Incl.	Over 5 to 8 Incl.	Over 8 to 11 Incl.	Over 11 to 14 Incl.
From	To, Incl.	From	To, Incl.				
0000	0	0.4600	0.3248	0.0044	0.0048	0.0051	0.0055
0	4	0.3248	0.2043	0.0039	0.0043	0.0046	0.0050
4	8	0.2043	0.1284	0.0034	0.0038	0.0041	0.0045
8	14	0.1284	0.0640	0.0029	0.0033	0.0036	0.0040
14	18	0.0640	0.0403	0.0025	0.0029	0.0033	0.0037
18	24	0.0403	0.0201	0.0020	0.0024	0.0028	0.0032
24	28	0.0201	0.0126	0.0016	0.0020	0.0024	0.0028
28	32	0.0126	0.0079	0.0013	0.0017	0.0020	0.0024
32	35	0.0079	0.0056	0.0010	0.0014	0.0017	0.0022
35	38	0.0056	0.0039	0.0008	0.0012	0.0015	0.0019

All tolerances plus or minus.

TABLE 1—MECHANICAL PROPERTIES FOR TEMPERS NO. 1 TO 3

Temper	B. & S. Gage No. From	B. & S. Gage No. To, Incl.	Thickness, In. From	Thickness, In. To, Incl.	Minimum Tensile-Strength, Lb. Per Sq. In.	Minimum Elongation in 2 In., Per Cent
1	12	16	0.0808	0.0509	12,500	30
	17	22	0.0508	0.0227	12,500	20
	23	26	0.0226	0.0159	12,500	10
2	12	16	0.0808	0.0509	18,000	7
	17	22	0.0508	0.0227	18,000	5
	23	26	0.0226	0.0159	18,000	5
3	12	16	0.0808	0.0509	22,000	4
	17	22	0.0508	0.0227	25,000	2
	23	26	0.0226	0.0159	30,000	2

without cracking. Sheet or strip of Temper No. 3 will not endure any considerable bending without cracking.

The usual variations in the thickness of sheet or strip are shown in Table 2.

General Information.—The specific gravity is about 2.70. Young's modulus of elasticity is about 10,000,000 lb. per sq. in.

Aluminum sheet and strip are used for many purposes where the requirements, either because of the service or the forming operations, are too specific to be covered in any general specification. It is usually advisable, therefore, to submit samples or drawings to the manufacturer to assist in the selection of the proper anneal or temper to suit the service or forming operations.

Aluminum sheet or strip is used for automobile bodies, hoods (special flat sheet), fenders, housing covers, floor covering, molding, instrument parts, instrument boards, hubcaps, wire wheel discs, brake-drum covers, miscellaneous pressed parts and for many parts in aircraft construction.

TABLE 2—PERMISSIBLE VARIATIONS

B. & S. Gage No. From	B. & S. Gage No. To, Incl.	Thickness, In. From	Thickness, In. To, Incl.	Permissible Variations, In
10	17	0.1019	0.0404	0.003
18	26	0.0403	0.0159	0.002

Specification No. 82, Brass Wire for Brazing

Composition in percentage:

Copper	59.00 to 62.00
Lead, max.	0.30
Iron, max.	0.06
Aluminum	None
Zinc	Remainder

This wire should be finished soft annealed. The surface should be clean and free from scale or other foreign materials.

General Information.—Wire in accordance with this specification is suitable for torch welding.

Specification No. 83, Soft or Annealed Copper Wire

Composition.—The copper shall be of such quality and purity that, when drawn and annealed, it shall have the properties and characteristics herein required.

Shapes.—These specifications cover untinned drawn and annealed round wire.

Finish.—The wire must be free from all imperfections not consistent with the best commercial practice.

Necessary brazes in soft or annealed wire must be made in accordance with the best commercial practice.

Specific Gravity.—For the purpose of calculating weights, cross-sections, and other purposes, the specific gravity of copper shall be taken as 8.89 at 20 deg. cent. (68 deg. fahr.).

Dimensions and Permissible Variations.—The size shall be expressed as the diameter of the wire in decimal fractions of an inch.

Wire shall conform to the following permissible variations in nominal diameter:

MECHANICAL REQUIREMENTS FOR SOFT COPPER WIRE

Diameter or Thickness, In. Over	Diameter or Thickness, In. To, Incl.	Tensile-Strength, Lb. Per Sq. In.	Elongation in 10 In., Per Cent
0.460	0.290	36,000	35
0.289	0.103	37,000	30
0.102	0.021	38,500	25
0.020	0.003	40,000	20

Wire 0.010 in. diameter and larger, 1 per cent over or under

Wire less than 0.010 in. diameter, 0.1 mil (0.0001 in.) over or under

Mechanical Requirements.—Wire shall be so drawn and annealed that its tensile strength and elongation shall not be greater nor less respectively than the values specified in the accompanying table. For wire whose nominal diameter is between the given sizes, the requirements shall be those of the next larger size included in the table.

Copper wire is usually purchased in B. & S. Gage.

Electrical Resistivity.—Electrical resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20 deg. cent. (68 deg. fahr.), and it shall not exceed 891.58 lb. per mile-ohm.

General Information.—As soft or annealed copper wire is so soft and ductile that it is easily marred by careless handling in the operation of winding or cabling, all testing and inspection must be done at the manufacturer's plant.

While international agreement upon the value 0.15328 ohms per meter-gram at 20 deg. cent. (68 deg. fahr.) for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electro-Technical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following equivalents have been prepared for the resistivity of copper at 20 deg. cent. (68 deg. fahr). 891.58 lb. per mile-ohm is equal to 0.15614 ohms per meter-gram, 1.7564 microhms per centimeter-cube, 0.69150 microhms per inch-cube or 10.565 ohms per mil-foot.

White Bearing Metals

(Proposed Extension of S.A.E. Standard)

At the meeting of the Non-Ferrous Metals Division on May 1 it was decided that the limits for the chemical compositions for the babbitt specifications, page D103 of the S.A.E. Handbook, should be closer for babbitt purchased in ingot form than for babbitt in castings; allowance being made for variations in composition due to casting. The present standard specifications are considered satisfactory for casting analyses. Therefore

The Division recommends the adoption of the extended specifications for White Bearing Metals Nos. 11, 12, 13 and 14

Specification No. 10, Babbitt

When finished bronze-backed bearings are purchased a maximum of 0.6 per cent lead is permissible in scraped samples provided a lead-tin solder has been used in bonding the bronze and the babbitt.

General Information.—This babbitt is very fluid and may be used for bronze-backed bearings, particularly for thin linings such as are used in aircraft engines. It is also suitable for die castings.

Composition in percentage:

	No. 10 Cast Products	No. 10A Ingots
Tin	90 to 92	90.75 to 91.25
Copper	4 to 5	4.25 to 4.75
Antimony	4 to 5	4.25 to 4.75
Lead, max.	0.35	0.35
Iron, max.	0.08	0.08
Arsenic, max.	0.10	0.10
Bismuth, max.	0.08	0.08
Zinc and Aluminum	None	None

Specification No. 11, Babbitt

Composition in percentage:

	No. 11 Cast Products	No. 11A Ingots
Tin	86.00 to 89.00	87.25 to 87.75
Copper	5.00 to 6.50	5.50 to 6.00
Antimony	6.00 to 7.50	6.50 to 7.00

General Information.—This is a rather hard babbitt which may be used for lining connecting-rod and shaft bearings which are subjected to heavy pressures; its "wiping" tendency is very slight. It is also suitable for die castings.

Specification No. 12, Babbitt

Composition in percentage:

	No. 12 Cast Products	No. 12A Ingots
Antimony	9.50 to 11.50	10.25 to 10.75
Copper	2.25 to 3.75	2.75 to 3.25
Lead	24.00 to 26.00	24.75 to 25.25

General Information.—This is a relatively cheap babbitt and is intended for bearings subjected to moderate pressures. It is also suitable for die castings.

Specification No. 13, Babbitt

Composition in percentage:

	No. 13 Cast Products	No. 13A Ingots
Tin	9.25 to 10.75	9.75 to 10.25
Antimony	14.00 to 16.00	14.75 to 15.25
Lead	74.00 to 76.00	74.75 to 75.25

General Information.—This is a cheap babbitt and serves successfully where the bearings are large and the service light. It should not be used as a substitute for a babbitt with a high tin content. It is also suitable for die castings.

Specification No. 14, Babbitt

Composition in percentage:

	No. 14 Cast Products	No. 14A Ingots
Tin	9.25 to 10.75	9.75 to 10.25
Antimony	14.00 to 16.00	14.75 to 15.25
Lead	74.00 to 76.00	74.75 to 75.25

General Information.—This is a cheap babbitt and serves successfully where the bearings are large and the service light. It should not be used as a substitute for a babbitt with a high tin content. It is also suitable for die castings.

STATIONARY-ENGINE DIVISION REPORT

T. C. Menges, *Chairman*	Associated Manufacturers Co.
L. F. Burger, *Vice-Chairman*	International Harvester Co.
H. G. Holmes	Novo Engine Co.
V. E. McMullen	Hercules Gas Engine Co.
I. J. Nelson	Nelson Bros.
O. A. Powell	Cushman Motor Works
L. W. Witry	Waterloo Gasoline Engine Co.

Flywheel Pulley Lugs

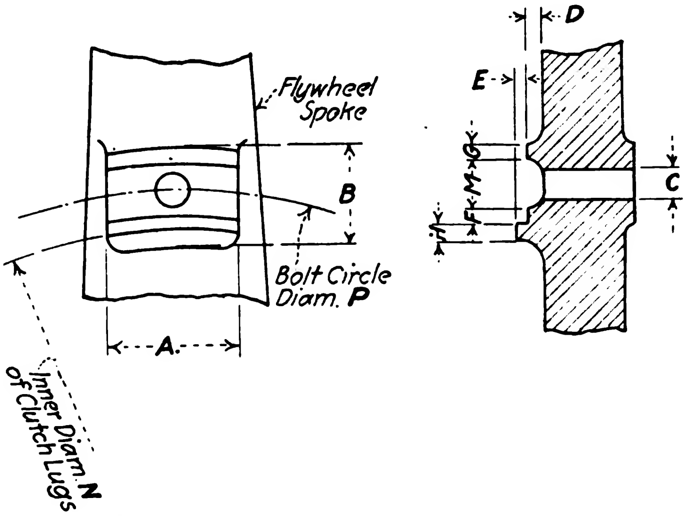
(Proposed S.A.E. Recommended Practice)

At the present time it is necessary for stationary internal-combustion engine builders to carry a large stock of pulleys in their branch houses to supply customers. This often necessitates carrying for 5 or 6 years in the distributors' stock pulleys for which there is practically no demand.

Appreciating this situation, L. F. Burger, of the International Harvester Co., was appointed a Subdivision of one at the February 1921 meeting of the Stationary-Engine Division to formulate a recommendation for flywheel pulley lugs. Mr. Burger submitted a recommendation that was subsequently extended at the suggestion of T. C. Menges, chairman of the Stationary-Engine Division, to include an additional size, the revised recommendation being approved by the members of the Division.

Information received in reply to a questionnaire sent to stationary-engine and pulley manufacturers showed that there is no general concordance of practice. This report should therefore be considered as an attempt to establish uniformity of pulley design to secure interchangeability and a minimum number of sizes. The manufacturers should have little trouble in eventually changing their product to the proposed dimensions. Once the standard is adopted in actual practice, each manufacturer will have to stock a much smaller number of pulleys. Therefore

The Division recommends that the flywheel pulley lug dimensions given in the accompanying table be adopted as S.A.E. Recommended Practice.



PULLEY AND FRICTION CLUTCH FASTENING LUGS

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*M*	*N*	*P*	Number of Lugs to Pulley or Clutch
1½	1¼	9/16	¼	3/16	¼	¼	¼	¾	8½	9¾	6
1¾	1½	9/16	¼	3/16	¼	¼	¼	¾	14	15¼	6
2	2¼	9/16	¼	3/16	¼	¼	3/8	1 3/8	16¼	17¾	6
2¼	2¼	9/16	¼	3/16	¼	¼	3/8	1 3/8	18¼	19¾	6

PARTS AND FITTINGS DIVISION REPORT

Division Personnel

F. G. Whittington, *Chairman*	Stewart-Warner Speedometer Co.
W. C. Keys, *Vice-Chairman*	Gabriel Mfg. Co.
Clarence Carson	Dodge Bros.
E. R. Douglas	Cincinnati Ball Crank Co.

H. B. Garman	Steel Products Co.
H. S. Jandus	C. G. Spring Co.
F. W. Slack	Peerless Motor Car Co.
C. W. Spicer	Spicer Mfg. Corporation
Alex Taub	General Motors Corporation
E. W. Weaver	Weaver & Kemble Co.

Passenger-Car Front Bumpers

(Proposed Extension of S.A.E. Standard)

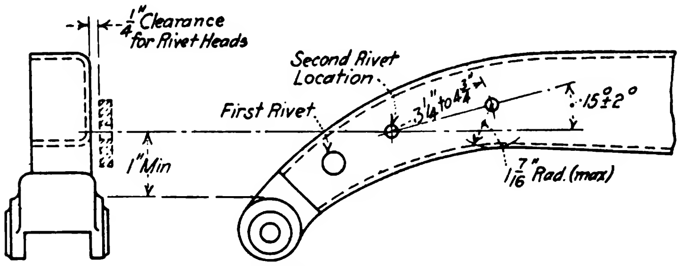
In 1921 a questionnaire was sent to passenger-car builders in the matter of the feasibility of standardizing a bolted-on front-bumper connection for passenger cars. Although it was pointed out that the adoption of such a standard would necessitate providing holes in the passenger-car frames, for use either by the car builders for mounting bumpers as standard equipment or by the car-owners for mounting bumpers as accessories, over 90 per cent of the companies replying recommended affirmative action. A Subdivision, consisting of F. G. Whittington, of the Stewart-Warner Speedometer Co., and E. W. Weaver, of Weaver and Kemble, was appointed to formulate a tentative recommendation.

As the bumper mounting is influenced largely by the frame design, a joint meeting of the Parts and Fittings and the Frames Divisions was held in November 1921, at which a report formulated by the Subdivision was discussed. The report was subsequently referred to passenger-car, bumper and rebound shock-absorber manufacturers for comment, and published in the April issue of The Journal.

The replies received, which were in general favorable, were summarized, referred to the members of the Division and discussed at the Division meeting in April. The report was revised at this meeting in certain details to make it conform as closely as possible with certain changes that were suggested. Therefore

> The Division recommends that the passenger-car front-bumper mounting shown in the accompanying illustration be adopted as an extension of the present S.A.E. Recommended Practice for Passenger-Car Front Bumpers, page C55 of the S.A.E. Handbook

The present S.A.E. Standard for Automobile Bumper-Mountings specifies that the distance from the center of the bumper face to the ground shall be 21 ft. for front bumpers and 22 in. for rear bumpers, the width of the bumper face, which shall be flat, to be 2 in. for front bumpers and 2½ in. for rear bumpers. The overall length of the bumper specified in both cases is from 59 to 60 in.



Two 11/16-in. diameter bolt-holes shall be located on or near the neutral axis of the frame section.

The first bolt-hole back from the spring eye may coincide with the first or second rivet hole.

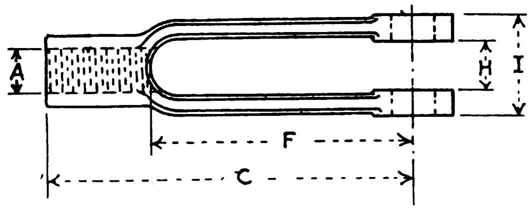
In cases where the second bolt-hole is to be used for mounting a shock absorbing device, the hole shall be located not more than 1 1/16 in. from the bottom of the frame channel at the nearest point.

Rod-Ends

(Proposed Extension of S.A.E. Standard)

Several communications were received by the Society to the effect that it was impossible to obtain ½-in. adjustable S.A.E. Standard rod-ends on the market with an adjusting length of 4 3/16 in. as specified in the present S.A.E. Standard on page C8 of the S.A.E. Handbook. It appears upon inquiry that the relative number of ½-in. adjustable yoke rod-ends 4 3/16 in. long sold at the present time is very small, the dimension generally used being 3 in. as specified in the original rod-end standard formulated by the Association of Licensed Automobile Manufacturers and adopted by the Society in 1911. The Parts and Fittings Division found that the rod-ends as specified in the present standard up to ½-in. nominal size are of comparatively light proportions, while those above the ½-in. nominal size are of comparatively heavy proportions. Therefore

> The Parts and Fittings Division recommends that the present S.A.E. Standard for Rod-Ends, page C8 of the S.A.E. Handbook, be extended by the addition of a ½-in. rod-end with a length of 3 in., the sizes to be classified as in the accompanying table.



LIGHT SERIES

A	C	F
3/16—32	1 9/16	1
¼—28	2	1¼
5/16—24	2¼	1 7/16
⅜—24	2½	1⅝
7/16—20	2⅞	1⅞
½—20	3	1⅞

HEAVY SERIES

A	C	F
½—20	4 3/16	3 1/16
⅝—18	4 15/16	3 11/16
¾—16	6⅛	4 9/16
⅞—14	7⅛	5¼
1 —14	8	6

Note: All other dimensions are the same as given in the table on page C9 of the S.A.E. Handbook.

Plain Steel Washers

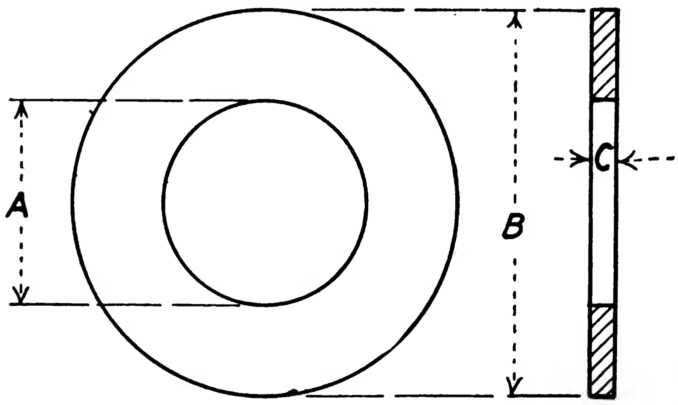
(Proposed S.A.E. Standard)

Last fall the Parts and Fittings Division was requested to prepare a standard for plain steel washers. Inasmuch as practice did not follow any established standard, a Subdivision was appointed to investigate the situation and prepare a report to the Division. At the last meeting of the Division data were submitted showing the die equipment in the possession of a number of washer manufacturers that conformed to a series of plain-washer sizes submitted to the Division and approved. The proposed series of sizes is intended for S.A.E. bolt sizes from ¼ to 1½-in. diameter and includes outside diameters that are suitable for use with U. S. standard hexagon nuts. Therefore

> The Parts and Fittings Division recommends the accompanying table of plain steel washer size for adoption as S.A.E. Standard

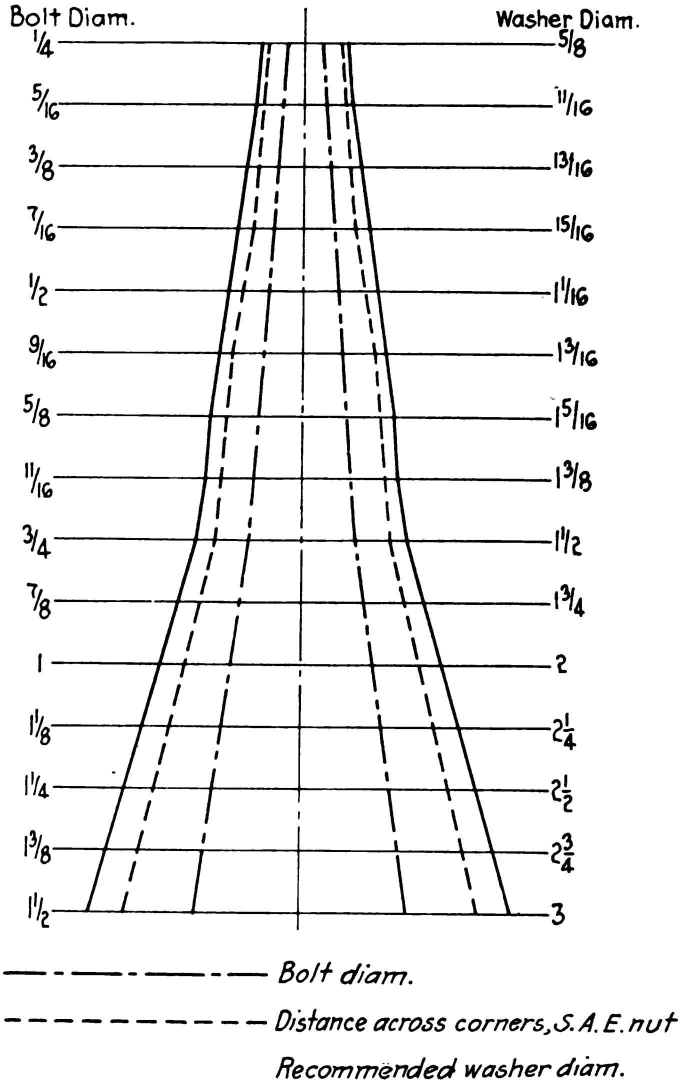
The chart accompanying this report shows the progression of S. A. E. bolt sizes, the plain washer inside

diameters, the distance across S.A.E. Standard hexagon bolt-heads and nuts and the outside diameter of the proposed washers.



Bolt. Diam.	WASHERS		
	A	B	C[3] ±0.010
1/4	9/32	5/8	1/16
5/16	11/32	11/16	1/16
3/8	13/32	13/16	1/16
7/16	15/32	15/16	1/16
1/2	17/32	1 1/16	3/32
9/16	19/32	1 3/16	3/32
5/8	21/32	1 5/16	3/32
11/16	23/32	1 3/8	3/32
3/4	13/16	1 1/2	1/8
7/8	15/16	1 3/4	1/8
1	1 1/16	2	1/8
1 1/8	1 3/16	2 1/4	1/8
1 1/4	1 5/16	2 1/2	5/32
1 3/8	1 7/16	2 3/4	5/32
1 1/2	1 9/16	3	5/32

[3] This dimension permits use of scrap stock. Washers shall be flat and free from burrs.



Ball Studs

(Proposed S.A.E. Recommended Practice)

In February 1919 a discussion was started of the Society standardizing ball-and-socket joints for reach-rods. The subject was assigned to the Miscellaneous Division and, after preliminary consideration, it developed into a study of current practice with regard to ball studs. Early in 1920 a large manufacturer of this product became interested and urged the adoption of standards as soon as possible. A Subdivision was then appointed, comprising

W. R. Strickland, *Chairman*	Peerless Motor Car Co.
E. E. Sweet	Lincoln Motor Co.

A tentative proposal was drafted and circulated and, in view of criticisms received, the work was reviewed and subsequently placed in the hands of a new subdivision, as conditions had arisen that prevented the original subdivision from continuing its work. The new subdivision consisted of

F. W. Slack, *Chairman*	Peerless Motor Car Co.
E. R. Douglas	Cincinnati Ball Crank Co.

A new report was prepared and distributed, following which the Division's recommendation was submitted to the Standards Committee at West Baden in May 1921. As a result of discussion at this meeting the subject was referred back to the Division for further study. Mr. Slack was then obliged to give up this work and another new subdivision was appointed, constituted of

E. R. Douglas, *Chairman*	Cincinnati Ball Crank Co.
H. G. Garman	Detroit Steel Products Co.
W. J. Outcalt	General Motors Corporation

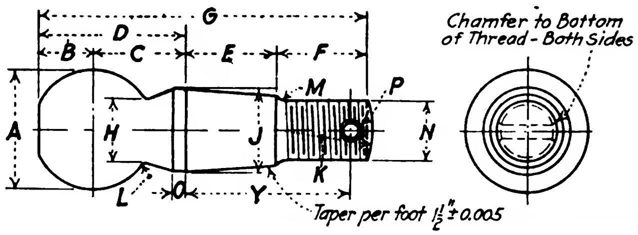
This Subdivision submitted a new report based on the earlier recommendations and the criticsims made, and was favorably considered by the Parts and Fittings Division at a recent meeting. Therefore

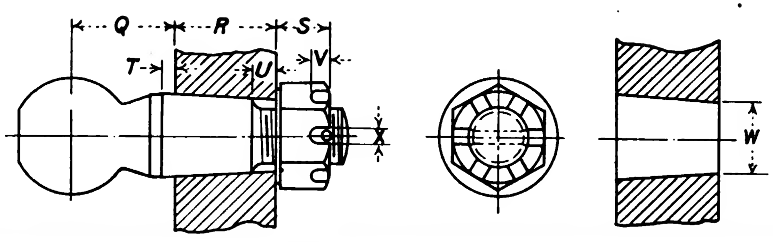
The Parts and Fittings Division recommends that the dimensions for ball studs specified herewith be adopted as S.A.E. Recommended Practice

Serrated Shaft Fittings

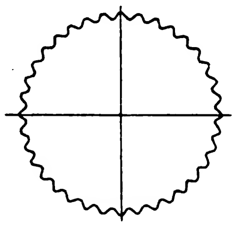
(Proposed S.A.E. Recommended Practice)

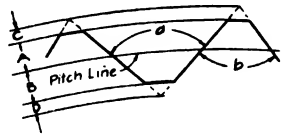
This subject was advanced for standardization in March 1920 by one of the large automotive parts manufacturing companies. The Parts and Fittings Division





A Nom.	A Actual	B	C	D	E	F	G	H	J	K	L	M	N S.A.E. Thr'd.	O	P Drill No.	Q	R max.	R min.	S	T	U	V	W	X	Y
1/2	31/64 ±0.005	7/32	7/16	21/32	7/16	1/2	1 19/32	9/32	13/32 ±0.002	3/8	1/32	1/32	5/16—24	3/32	48	9/16 +0 −3/64	19/32	33/64	17/64	1/8 +0 −3/64	13/64 +0 −3/64	3/32	0.329 ±0.001	5/64	27/32
5/8	39/64 ±0.005	9/32	9/16	27/32	9/16	1/2	1 29/32	11/32	15/32 ±0.002	1/2	3/64	1/32	5/16—24	3/32	48	11/16 +0 −3/64	23/32	41/64	17/64	1/8 +0 −3/64	13/64 +0 −3/64	3/32	0.376 ±0.001	5/64	31/32
3/4	47/64 ±0.005	5/16	5/8	15/16	5/8	9/16	2 1/8	13/32	35/64 ±0.002	5/8	3/64	1/32	3/8—24	7/64	36	25/32 +0 −3/64	25/32	43/64	21/64	5/32 +0 −3/64	13/64 +0 −3/64	1/8	0.446 ±0.001	1/8	1 5/64
7/8	55/64 ±0.005	3/8	11/16	1 1/16	11/16	3/4	2 1/2	15/32	5/8 ±0.002	5/8	1/16	1/16	1/2—20	1/8	36	55/64 +0 −3/64	29/32	25/32	7/16	11/64 +0 −3/64	17/64 +0 −3/64	9/64	0.509 ±0.001	1/8	1 5/16
1	31/32 ±0.010	7/16	3/4	1 3/16	3/4	3/4	2 11/16	9/16	45/64 ±0.002	3/4	1/16	1/16	1/2—20	1/8	36	15/16 +0 −1/16	31/32	27/32	7/16	3/16 +0 −1/16	9/32 +0 −1/16	9/64	0.578 ±0.002	1/8	1 3/8
1 1/8	1 3/32 ±0.010	1/2	27/32	1 11/32	27/32	29/32	3 3/32	5/8	25/32 ±0.002	1	1/16	1/16	5/8—18	5/32	28	1 3/64 +0 −1/16	1 5/64	15/16	35/64	13/64 +0 −1/16	19/64 +0 −1/16	3/16	0.642 ±0.002	5/32	1 19/32
1 1/4	1 7/32 ±0.010	9/16	15/16	1 1/2	15/16	29/32	3 11/32	11/16	7/8 ±0.002	1	3/32	1/16	5/8—18	5/32	28	1 1/8 +0 −1/16	1 11/64	1 3/64	35/64	13/64 +0 −1/16	19/64 +0 −1/16	3/16	0.725 ±0.002	5/32	1 11/16
1 1/2	1 15/32 ±0.010	5/8	1 1/8	1 3/4	1 1/8	1 1/16	3 15/16	13/16	1 1/32 ±0.002	1 1/4	3/32	1/16	3/4—16	3/16	28	1 11/32 +0 −1/16	1 3/8	1 7/32	21/32	7/32 +0 −1/16	5/16 +0 −1/16	7/32	0.855 ±0.002	5/32	2
1 3/4	1 23/32 ±0.010	3/4	1 3/8	2 1/8	1 3/8	1 7/32	4 23/32	15/16	1 1/4 ±0.002	1 1/4	1/8	1/16	7/8—14	13/64	28	1 5/8 +0 −1/16	1 21/32	1 15/32	49/64	1/4 +0 −1/16	11/32 +0 −1/16	1/4	1.039 ±0.002	5/32	2 25/64
2	1 15/16 ±0.015	7/8	1 1/2	2 3/8	1 1/2	1 11/32	5 7/32	1 1/8	1 3/8 ±0.003	1 1/2	1/8	1/16	1 —14	7/32	28	1 25/32 +0 −5/64	1 25/32	1 37/64	7/8	9/32 +0 −5/64	23/64 +0 −5/64	1/4	1.147 ±0.002	5/32	2 5/8
2 1/4	2 3/16 ±0.015	1	1 11/16	2 11/16	1 11/16	1 1/2	5 7/8	1 1/4	1 9/16 ±0.003	2	1/8	3/32	1 1/8—12	1/4	11	1 63/64 +0 −5/64	2 1/32	1 13/16	63/64	19/64 +0 −5/64	27/64 +0 −5/64	5/16	1.304 ±0.002	7/32	2 15/16
2 1/2	2 7/16 ±0.015	1 1/8	1 7/8	3	1 7/8	1 5/8	6 1/2	1 3/8	1 3/4 ±0.003	2	3/16	3/32	1 1/4—12	17/64	11	2 11/64 +0 −5/64	2 7/32	2	1 3/32	19/64 +0 −5/64	27/64 +0 −5/64	5/16	1.468 ±0.002	7/32	3 15/64
3	2 15/16 ±0.015	1 1/4	2 1/4	3 1/2	2 1/4	1 7/8	7 5/8	1 5/8	2 1/16 ±0.003	2 1/2	3/16	3/32	1 1/2—12	19/64	2	2 37/64 +0 −5/64	2 19/32	2 11/32	1 5/16	21/64 +0 −5/64	27/64 +0 −5/64	3/8	1.733 ±0.002	1/4	3 53/64





A and B are Nominally Equal
A + B = Depth of Cut
C in Hole and D in Shaft may be made as desired by each individual manufacturer beyond min and max as specified in table
N = Number of Serrations

Nominal Diam.	Pitch Diam.		N	a, deg.	b, deg.	HOLE			SHAFT		
						Large Diam. Min.	Small Diam.		Outside Diam.		Inside Diam. Max.
	Max.	Min.					Max.	Min.	Max.	Min.	
1/8	0.122	0.120	36	90	80	0.125	0.118	0.117	0.124	0.123	0.116
3/16	0.182	0.180	36	90	80	0.187	0.176	0.175	0.186	0.185	0.174
1/4	0.243	0.241	36	90	80	0.250	0.235	0.234	0.249	0.248	0.233
5/16	0.303	0.301	36	90	80	0.312	0.293	0.292	0.311	0.310	0.291
3/8	0.363	0.361	36	90	80	0.375	0.352	0.351	0.374	0.373	0.350
1/2	0.485	0.483	36	90	80	0.500	0.469	0.468	0.499	0.498	0.467
5/8	0.605	0.603	36	90	80	0.625	0.584	0.583	0.624	0.623	0.582
3/4	0.733	0.731	48	90	82 1/2	0.750	0.716	0.714	0.749	0.747	0.713
7/8	0.855	0.853	48	90	82 1/2	0.875	0.835	0.833	0.874	0.872	0.832
1	0.977	0.975	48	90	82 1/2	1.000	0.954	0.952	0.999	0.997	0.951
1 1/8	1.098	1.096	48	90	82 1/2	1.125	1.071	1.069	1.124	1.122	1.068
1 1/4	1.220	1.218	48	90	82 1/2	1.250	1.190	1.188	1.249	1.247	1.187
1 3/8	1.342	1.340	48	90	82 1/2	1.375	1.309	1.307	1.374	1.372	1.306
1 1/2	1.464	1.462	48	90	82 1/2	1.500	1.428	1.426	1.499	1.497	1.425
1 3/4	1.708	1.706	48	90	82 1/2	1.750	1.666	1.664	1.749	1.747	1.663
2	1.952	1.949	48	90	82 1/2	2.000	1.904	1.902	1.999	1.997	1.901
2 1/4	2.196	2.193	48	90	82 1/2	2.250	2.142	2.140	2.249	2.247	2.139
2 1/2	2.440	2.437	48	90	82 1/2	2.500	2.380	2.378	2.499	2.497	2.377
2 3/4	2.684	2.681	48	90	82 1/2	2.750	2.618	2.616	2.749	2.747	2.615
3	2.928	2.925	48	90	82 1/2	3.000	2.856	2.854	2.999	2.997	2.853

All dimensions in inches.

referred the matter to C. W. Spicer as a Subdivision to draft a report. A questionnaire was sent to 75 companies, most of which submitted data, which were tabulated and used by Mr. Spicer as a basis for his report. The investigation showed that both taper and straight serrated-shafts are used extensively, although the practice is better defined for the taper type. The Subdivision's report was discussed in detail by the Parts and Fittings Division at a meeting held recently. Sizes below the ½-in. taper fitting have not been included in the recommendation because they are used very little if at all. The number of serrations on the taper fittings is already practically standard, whereas the number of serrations on the straight shafts varies considerably. The Division has, however, selected the serrations on straight shafts as shown in the report as providing a suitable number of well proportioned serrations. Therefore

> The Parts and Fittings Division recommends that the taper and straight shaft-serrations shown in the accompanying illustrations and tables be adopted as S.A.E. Recommended Practice for Serrated Shaft Fittings

Tank and Radiator Caps

(Proposed Extension of S.A.E. Recommended Practice)

Trouble has been experienced by the gasoline-pump manufacturers in providing suitable nozzles for pump equipment because of the lack of uniformity in the size

(Concluded on page 523)

Overhead Camshaft Passenger-Car Engines

By P. M. Heldt[1]

Semi-Annual Meeting Paper *Illustrated with* Drawings

THE gradual trend toward overhead valves in automobile engines, as indicated by an increase in their use on American cars from 6 per cent in 1914 to 31 per cent in 1922, has been accelerated, in the opinion of the author, by their successful application to aircraft engines and by the publicity given them by their almost universal adoption on racing machines. Tractor engines recently brought out show the advantage of this construction. Methods of operating valves in the cylinder-head; the advantages of the valve-in-the-head construction as regards the form of combustion space, engine cooling and high-speed operation; the reason for using an overhead camshaft to operate the valves on racing engines, the question of noisy operation and the possibility of having an overhead camshaft engine operate as quietly as one in which the camshaft is enclosed in the crankcase; the location of the drive in the various foreign engines of the overhead camshaft type; the silent operation that is possible with a rear drive; the use of chains and spur, helical, worm and spiral bevel gears for the camshaft drive, with the advantages and disadvantages of each method and descriptions of specific applications; and some radical designs of overhead camshaft drive and valve-actuating mechanism that have been developed abroad are among the topics discussed. The three methods of operating the valves: (*a*) directly through the action of cams on followers secured to the end of the valve-stem, (*b*) through the interposition of single-armed levers or adjusting blades between the cams and the valve-stems, and (*c*) by the use of tappet levers, are also outlined with particular reference to the specific applications of each. Numerous illustrations supplement the text.

FOR a number of years there has been a gradual trend toward the use of overhead valves in automobile engines. This movement probably was accelerated by the success of aircraft engines with this valve arrangement, as well as by the publicity given to this construction by its almost universal use on racing engines. That valves located directly in the cylinder-head are not merely a fad but possess practical advantages can be concluded from the fact that practically all the tractor engines brought out during recent years have the valves so located.

Valves in the cylinder-head can be operated either by tappet-rods extending up one side of the engine or directly from an overhead camshaft. A third method, which consists of arranging the valves at right angles to the cylinder axis and operating them from a camshaft in the crankcase through the intermediary of long, double-armed levers, is exemplified in the Duesenberg engine. This arrangement necessitates the provision of a valve-pocket on top of the cylinder-head, and in most respects, especially as regards the form of the combustion-chamber, resembles the L-head engine more than the true valve-in-head engine which has no valve-pockets.

The advantage of the valve-in-head engine over the L and T-head types is that the combustion space has a much more favorable form. It has less cooling area in proportion to the volume than either of the other types. Consequently the heat loss to the jacket is reduced, and the distances from the firing points to the most remote part of the firing chamber are smaller, so that the flame is propagated through the combustible charge in a shorter interval of time. This tends toward increased power and higher fuel economy. The decrease in the loss of heat to the water-jacket due to the simple form of the combustion-chamber also facilitates the problem of effective engine cooling. The combustion-chamber, the portion of the cylinder casting subjected to the highest temperatures, is more symmetrical and the cylinders therefore are less likely to be distorted by unequal expansion. There is also less likelihood of the presence of masses of metal in the upper part of the cylinder casting that would be difficult to cool, as well as of the formation of steam pockets.

While considerable emphasis is laid on the advantages of the valve-in-head construction from the standpoint of engine cooling, the majority of designers who have adopted the practice have done so because they expected increased engine power and reduced fuel-consumption. The inlet as well as the exhaust-valve passages can be made shorter and more direct than in any other form of cylinder, and the overhead-valve type of engine lends itself particularly well to high-speed operation. It is also claimed that there is less tendency to knock. In view of the greater ease of effectively cooling the combustion-chamber this claim does not sound altogether unreasonable, but no definite proof of it seems to be available.

The tendency toward the overhead-valve type of engines is reflected by the analyses of car specifications that are being made annually. In 1914 only 6 per cent of the cars listed had such valves, while in 1922 the percentage had increased to 31. This applies to American cars. In Europe the valve-in-head engine has made progress, particularly during the last year. Disregarding engines of the sleeve-valve type, 32 per cent of the European models listed in 1922 had overhead valves, as against 20 per cent in 1921. British companies seem to be in a state of transition, many of them offering cars this year with both valve-in-head and side-pocket-valve engines.

Tappet-Rods and Overhead Camshafts

In most engines of the valve-in-head type used on passenger cars the valves are operated by tappet-rods, whereas in most racing and aircraft engines they are operated by overhead camshafts. It is interesting to analyze the reasons for this difference. The side-rod method of overhead-valve operation is the older, at least in the sense that it was the first to gain much popularity. In one way it is also the simpler and more natural, for all that is wanted is a reciprocating motion, and

[1] M.S.A.E.—Engineering editor, Class Journal Co., New York City.

what means of transmitting a plain reciprocating motion over a moderate distance could be simpler than a push-rod? However, when engines attain high speeds the problems arising from inertia effects must be considered, and in order to permit high-speed operation overhead valves are generally employed. Increased power output results directly from the increased operating speed and the gain in economy is also in part dependent upon it.

In racing and ultra high-speed engines the speed of the engine is limited by the inability of the valves to close promptly at extremely high speeds. The inertia of the reciprocating parts of the valve becomes so great that it is practically impossible to get the cam followers to follow the contour of the cams. The force necessary to close the valves that is furnished by the valve-springs becomes greater in direct proportion to the weight of the reciprocating parts of the valve. In one sense there is almost no limit to the force that can be obtained from a spring, but in practice, if the pressure of the valve-spring is increased, the stress in the material of the spring generally is increased also with a consequently greater risk of breakage of the spring. A very stiff spring puts great stresses upon the valve itself. In order to permit higher operating speeds it is generally a much better plan to reduce the weight of the reciprocating parts of the valve than to increase the stiffness of the springs. To reduce the stress on the valves and their springs at extremely high speeds, motion should be transmitted in the rotating form as close to the valves as possible and then converted into a reciprocating motion. This is the reason that racing engines are so frequently provided with overhead camshafts.

Another aspect of the valve problem that needs consideration, particularly in connection with its application to passenger-cars, is the requirement that engines shall operate without appreciable noise. One cause of noisy operation is the clearance that must be given the valves, particularly the exhaust-valves, when they are cold. The need for this clearance is due to the fact that as the engine heats up the exhaust-valve stem expands much more than the engine as a whole and must be given freedom in which to expand or the valve will not close; a condition that is generally followed by disastrous results. If the cams are directly over the valves the chances of unequal expansion and the consequent need for clearance are greatly reduced. In this connection the relative temperatures of the cylinder-block and the valve-rods at the side are factors. If the cylinders are air-cooled and the valve-rods are located so that they are not greatly influenced by the heat of the cylinders but remain relatively cool, it is conceivable that the cylinders will expand much more than the rods. This difference in expansion has the same effect as the expansion of the valve-stems, and additional clearance must be allowed the valves. On the other hand, if the engine is water-cooled and the valve-rods extend through enclosed spaces within the cylinder-block, the rods and the block will be of substantially the same temperature and there will be no difference in expansion. Noiseless operation is not important in racing and aircraft engines.

There seems to be a general impression that it is difficult to make overhead camshaft gears operate noiselessly. Just why this should be so, if it is so, is not immediately apparent. Noise in cam gearing depends on the one hand on the cam outline, which could be made the same as in engines with the camshaft in the crankcase; and on the other hand on the mass of the reciprocating parts, that, as already pointed out, can be, and usually is, considerably less than in a valve-in-head engine in which the valve-rods extend up the sides. It may be that the impression was created in the early days when overhead camshafts were exposed. In modern engines of this type not only the camshaft but the whole valve mechanism is enclosed, so that it should be as easy to render an engine of this construction noiseless as one with the camshaft in the crankcase.

If there is any justification for the belief, the reason probably is that there are generally more wearing contacts in overhead camshaft gearing than in the more conventional type. At each of the contacts wear will occur and the play or slackness in the camshaft operating train therefore will increase more rapidly than in the ordinary L-head engine. Every time the nose of a cam passes from under the cam follower there is a tendency, which is more pronounced in the case of a four-cylinder engine than in one with more cylinders, for the camshaft to jump ahead and take up the slack of the drive, thus creating noise.

In connection with the older engines with side tappet-rods the rapid wear of the tappet-lever bearings is unpleasantly remembered. The only means of lubrication of these tappet-levers was an oil-hole and the excessive wear was probably due not so much to the inadequacy of the lubricating means as to neglect to make use of them. Presumably with the newer engines of this type having wick or even force-feed lubrication this difficulty has been overcome. With some of the overhead camshaft engines tappet-levers are also used, but they are now always enclosed and therefore can be effectively lubricated. The difference is therefore not one of camshaft location but rather of valve actuation and details of construction. Another thing in favor of the overhead camshaft is that it generally leads to a very symmetrical engine with the accessories so located that they are quite accessible and with the sides of the engine comparatively free from obstructions.

One method of judging an overhead-valve engine is by the facility for removing the cylinder-head for cleaning out the carbon by scraping and for grinding the valves. In an engine with the camshaft in the crankcase, the amount of disassembling and reassembling necessary for these two jobs is usually the same, but in the case of an overhead camshaft engine, this does not hold true. In many designs the whole camshaft and overhead valve-operating gear must be taken apart before the valves can be ground in, and this, of course, is a rather serious objection.

From the standpoint of manufacturing cost the overhead camshaft is not a very attractive proposition. The provisions that must be made for the complete, oil-tight enclosure of the camshaft for lubrication, the enclosure of the drive between members, of which one is carried by the crankcase and another by the cylinder-head, and the lubrication of this drive, involve considerable expense. There are ways of producing overhead camshaft engines comparatively cheaply but these engines are likely to prove unsatisfactory.

The overhead camshaft engine has not yet made much headway in this Country, only four cars that are at all well known having such engines at present. In Europe. on the other hand, many of the leading makes now employ this type of engine. These include Lanchester, Napier, Wolseley, Straker-Squire and Leyland in England; Bugatti, Farman and Hispano in France; Ansaldo and Diatto in Italy and Mercedes and Szawe in Germany. As a passenger-car engine the overhead camshaft type is practically an after-war product, but motor-truck engines

thus equipped were used by several companies in Germany prior to the war. I assume that the four American overhead camshaft engines, the Wills-Sainte Claire, the Leach Biltwell, the Duesenberg and the Frontenac, are well known, as all have been described in the technical journals within the past several months; consequently, only overhead camshaft engines of foreign design will be considered.

Location of Drive

In connection with the drive the question of its location at the front or rear comes up. It is the almost universal practice to have the camshaft drive at the front and this location is practically standardized. It is well known that trouble has been experienced with camshaft drives in the last few years and there is suspicion that the fact that the drive is at the front, where it is subjected to the effects of torsional vibration of the crankshaft, has something to do with it. Since the introduction of engines with six and more cylinders running at high speeds a great deal of trouble has been caused by torsional vibration. Owing to the periodic impulses in a gasoline engine, the engine naturally tends to accelerate and decelerate periodically and the flywheel is provided to minimize these speed fluctuations. The greatest fluctuations of speed occur at the forward end of the crankshaft. If the natural period of vibration of the shaft happens to coincide with the periodicity of the impulses received by this end of the shaft, a periodic torsional rocking motion is superimposed upon the regular rotary motion of the shaft. After each explosion in one of the forward cylinders the crankshaft will jump ahead, only to snap back the next moment. This effect, of course, occurs only at certain critical speeds of the engine and in engines with exceedingly stiff crankshafts these speeds may never be reached in regular operation. Where a critical speed is reached in the regular operation of the engine it is obvious that it must be rather hard on the camshaft gears if they are located at the forward end.

Mercedes for many years has located the camshaft gears at the rear as shown in Fig. 1 and another German maker, Szawe, has recently followed this example. If there is any part of the crankshaft that rotates more uniformly than the rest, it is the part at the flywheel. This, therefore, would seem to be the best part from which to take the camshaft drive. The objection has been made that this location renders the camshaft gears

Fig. 1—Mercedes Overhead Camshaft Engine with Rear End Camshaft Drive

Fig. 2—British A. C. Engine with Chain-Driven Overhead Camshaft

much less accessible. This is true, but if it renders the gears at the same time invulnerable, what does it matter? With the light work the camshaft gears really have to do it should not be difficult to provide a set of gears that would last the life of the engine. In that case the question of accessibility would not arise.

I believe that anyone contemplating the production of an engine with an overhead camshaft should give the location of the camshaft driveshaft the fullest consideration, especially if the engine has six or more cylinders. From the standpoint of silent operation also the rear drive have something to commend it and conditions are still further improved when the fan is driven from the forward end of the camshaft, making the resulting or total torque on the camshaft non-reversible and thus eliminating the cause of noisy operation referred to in the foregoing.

Silent Chain and Spur Gear Drives

One method of driving an overhead camshaft is by silent chains and this has been used in a few cases for many years. One of the four American overhead camshaft engines, the Frontenac, has this form of drive. From the manufacturing standpoint the chain drive is very attractive, as apparently all that is required is a sprocket wheel on the crankshaft and another on the camshaft and a chain to connect the two. In practice however various difficulties crop up which have militated against the more extensive use of chains. A single chain between the crankshaft and camshaft is unsatisfactory because it would have to be abnormally long, and with the wearing of the links or the "stretching" of the chain it would whip and be likely to hit the wall of the casing, unless the latter was made with a large clearance space. Two chains therefore are generally used, one transmitting the motion to a short intermediate shaft, which may be the fan shaft, and the other transmitting it from this shaft to the camshaft. This does not dispose of the question of chain adjustment however. One way of solving this problem consists in driving not directly to the camshaft but to a short shaft at the end of it that drives the camshaft through a Hookham joint, and then providing both this short shaft and the intermediate or fan shaft with an eccentric adjustment. Another method consists of the use of chain-tightening idlers.

In the British A.C. six-cylinder engine the camshaft drive is by a long silent chain direct from the crankshaft to the camshaft, with a spring-loaded jockey pulley to take up the slack. The drive is at the rear end of the

FIG. 3—THE UPPER PORTION OF THE NAPIER OVERHEAD CAMSHAFT ENGINE

engine, as is shown in Fig. 2. The ill-effects of the intermittent torque that the chain must withstand, even in this six-cylinder engine, are reduced in a degree by reason of the water-circulating pump being located at the end of, and driven directly by, the camshaft; the load represented by the pump being positive and uniform puts the torque always above the zero line, and though it does not eliminate or even reduce the torque variations due to cam-succession it maintains a positive pressure between the teeth of the sprockets and the chain. For this reason such a pump location seems to be worth considering, particularly on four-cylinder engines, no matter what form of drive is used.

On the Wolseley engine there is a short silent chain for transmitting power to an intermediate shaft directly above the crankshaft. Because of the shortness of this chain the troubles of whipping, and the like, are absent and no means for tightening the chain are required.

The spur-gear drive has given excellent service on racing engines. This involves a train of spur-gears extending up the front of the engine, and one would expect it to be rather difficult to make such a train run quietly, even if helical teeth were used. In racing engines the shafts of the intermediate gear are mounted on ball bearings, and this would no doubt also be required in high-class passenger-car engines, which would make the drive rather expensive. Another objection to the spur-gear train is that, since there are a number of wearing surfaces, when the gears begin to show serious wear a considerable backlash will soon develop. It would then probably be almost impossible to keep the drive quiet. The gears might be so liberally proportioned that the wear would be a negligible quantity, but the high cost and the rather unsightly appearance of the large gearcase would remain. An advantage shared by the two methods of drive is that they require no thrust bearings, whereas all the other more common forms of drive require such bearings. These involve considerable expense, including not only the cost of the bearings themselves but also that of machining the mountings and fitting the bearings.

A form of drive for overhead camshafts that has met with success and is now used on several well-known makes of cars is that through helical gears with axes at right angles, or the worm drive. Formerly the so-called

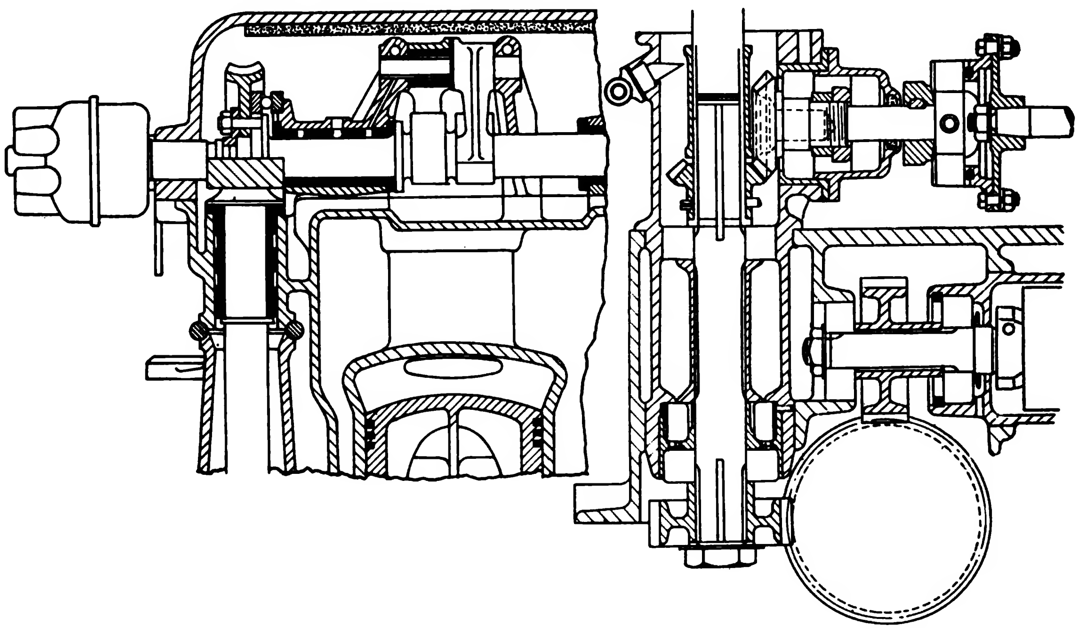


FIG. 4—CAMSHAFT DRIVE OF LANCHESTER ENGINE

FIG. 5—DETAILS OF THE ANSALDO ENGINE
A Cross-Section of the Upper Portion Is Presented at the Left and the Middle Drawing Is a Side View of the Same Portion. The View at the Right Gives Details of the Camshaft Drive

spiral gears were used to a great extent for the camshaft drives of stationary gas engines. Their most valuable feature is their silent operation. If made of liberal size and provided with adequate means of lubrication they give satisfactory service, but as there is theoretically only point contact the unit pressure at the contact surface is quite high and if the lubrication is not dependable the backlash is likely to increase rapidly. For this reason several British manufacturers use true worm gears for the drive. Worm gears differ from helical gears in that the face of the wormwheel is throated, conforming to the circumference of the worm, whereby an increased bearing surface is obtained. One advantage of the helical gear or worm drive is that the vertical shaft is offset from both the crankshaft and the camshaft and therefore can have extensions for accessories coupled to it at both the top and the bottom. With a bevel-gear-driven intermediary shaft extra gearing is required for accessories at least at the bottom.

It is probably between the worm gear and the spiral bevel gear that the chief competition for supremacy in the overhead camshaft field will arise. The strong and the weak points of the two are practically the same. Both are absolutely quiet in operation, which constitutes their strong point, but both require means for the accurate adjustment of the mesh if they are to work satisfactorily. The advantage of worm gear in respect to greater handiness for the driving of accessories in certain locations is offset by its somewhat lower efficiency and lack of symmetry.

An overhead camshaft is one of the features of the six-cylinder aluminum engine brought out by Napier of England some years ago. The camshaft is hollow and is supported in seven cast brackets bolted to the aluminum cylinder-head as is shown in Fig. 3. It is located centrally above the cylinders. The valves are staggered, one being on one side of the camshaft and the other on the opposite side. There are two rocker-shafts supported on the same brackets as the camshaft. The rockers or valve-levers extend underneath the camshaft and are arranged so as to give a lift to the valves greater than the height of the cam nose. The camshaft drive on this engine is by worm gearing. The vertical shaft is made in three parts: one carried by the housing at the forward end of the crankcase; the second carried by the cylinder-head; and the third an intermediate shaft secured to the top and bottom parts by flanged couplings. From the bottom of the vertical shaft the oil-pump is driven, while the generator and magneto drive is taken off at the joint between the bottom and the intermediate section, the worm being combined with a coupling flange.

In connection with the Napier camshaft drive a description may be given of its camshaft brake, a feature found only on a few high-grade engines. A camshaft brake may be more necessary in an engine having a worm drive for the camshaft than in an ordinary L-head engine with direct spur-gear drive to the camshaft, owing to the fact that the worm drive might permit more backlash in the drive. The object of the camshaft brake is, of course, to prevent the camshaft from snapping ahead as the nose on any particular cam passes its follower. The brake consists of a metal disc mounted in the housing of the worm gear in such a manner that it cannot rotate but is forced against a flange on the rim of the worm gear by a coiled spring in a mounting hub bolted to the worm-gear housing from the outside. Adjustment is apparently provided for by washers under the flange of this hub.

Details of the camshaft drive on the Lanchester and Ansaldo engines are presented in Figs. 4 and 5.

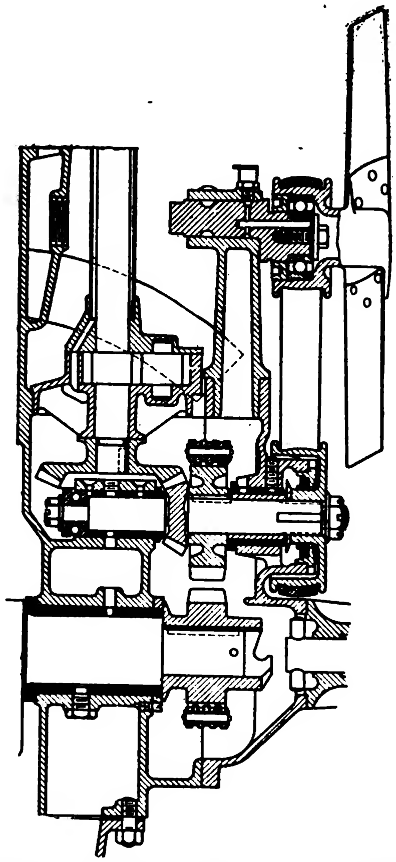


FIG. 6—OVERHEAD CAMSHAFT DRIVE ON THE WOLSELEY ENGINE

FIG. 7—THE UPPER PORTION OF THE WOLSELEY OVERHEAD CAMSHAFT ENGINE

SPIRAL BEVEL GEAR DRIVE

Probably the most prominent make of small car employing an overhead camshaft is the Wolseley. The construction which is shown in Figs. 6 and 7 is similar in some respects to that on the Napier engine but is simplified. The drive of the camshaft is by spiral bevel gear instead of worm gear. The spiral bevel gear drive is preceded by a silent chain drive from the crankshaft to a parallel shaft directly above it, at a ratio of 1 to 1 and with a very short chain. The 2 to 1 reduction is obtained by the lower pair of bevel gears which permits the use of a small pair of gears at the top, thus making for neatness. It would be practically impossible to obtain this reduction at the bottom of the vertical shaft and still have the driving pinion on the crankshaft, for the reason that to clear the crankshaft bearing the pinion must be of large diameter, and this would necessitate such a large-diameter driven gear that the whole drive would become unduly bulky. As it is, the fan-drive pulley is mounted on a forward extension of the horizontal shaft and the gear type oil-pump forms part of the mounting of the vertical shaft. The shafts of this drive are mounted in plain bearings exclusively, except for a ball thrust-bearing on the horizontal shaft. This is a small-bore four-cylinder engine with the camshaft supported in two bearings only. To reduce the unsupported length as much as possible, the two rearmost cams are arranged to overhang the rear bearing. The general arrangement of the valves, rocker-levers and cams is practically the same as on the Napier. Both the camshaft and rocker-lever shafts are supported by brackets on the cylinder-head, the rocker levers being located underneath the camshaft and giving a greater lift to the valves than what might be called the cam throw. Clearance adjustment is made by set screws in the ends of the levers which are locked by clamping bolts in the split ends of the levers.

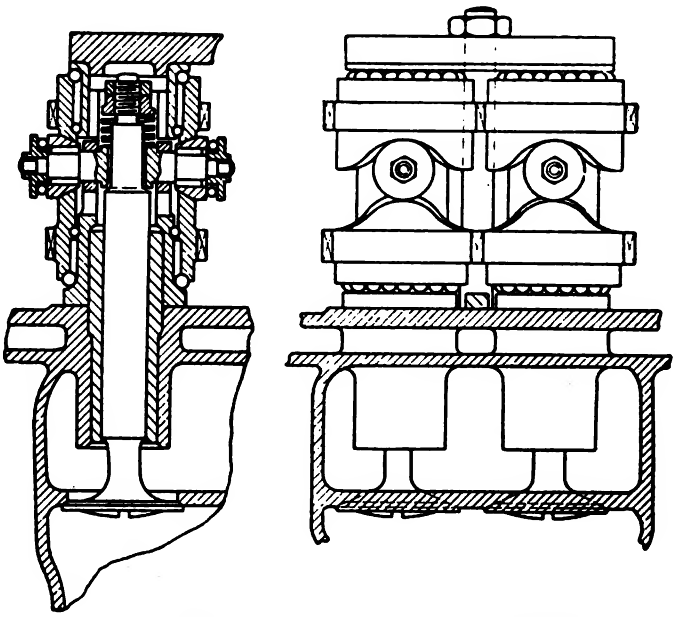


FIG. 9—OVERHEAD CAM GEAR ON THE FIAT ENGINE

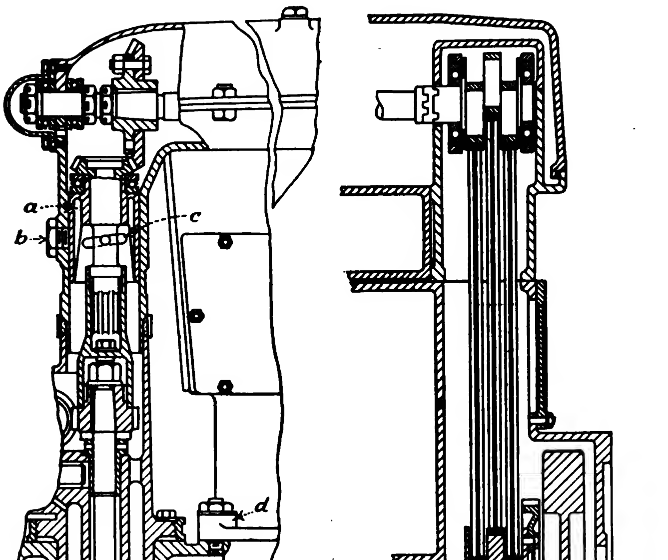


FIG. 8—AT THE LEFT THE CAMSHAFT DRIVE USED ON THE BENTLEY ENGINE AND AT THE RIGHT A SOMEWHAT UNUSUAL FORM OF CAMSHAFT DRIVE THAT IS USED ON THE LEYLAND STRAIGHT-EIGHT ENGINE

The spiral bevel-gear drive seems to have much to recommend it for overhead camshaft engines, but it must be realized that in order that the gears may run together quietly and efficiently they must be adjusted accurately. As there are two pairs of gears four adjustments are required and provision must be made for any lack of alignment or relative motion due to differences in heat expansion between the upper and lower bearings of the vertical shaft.

This problem has been attacked by two engineers of Bentley Motors, Ltd., an English company, that has taken out several patents covering a number of points of de-

sign. Referring to the left-hand portion of Fig. 8, the vertical shaft is made in two parts, which are joined by a telescopic splined coupling. Each part can be accurately adjusted endwise with or in its casing. At the bottom this is accomplished by providing the casing with a flange, which, instead of being bolted directly to the crankcase, is provided with a threaded ring. This ring can be screwed up or down over the integral flange and with it forms a flange of adjustable thickness. At the top a bearing box *a* can be rotated slightly by inserting a bar through the hole closed by plug *b*, and by being rotated is adjusted up or down by means of the helical slots *c* and pin screws in the casing extending into them. The camshaft is held against endwise motion by two thrust bearings at the forward end, and can be adjusted endwise by simultaneously turning the two nuts at the opposite sides of these bearings. It will be noted that the upper part of the casing for the vertical shaft is integral with the camshaft casing while the lower part is integral with the crankcase and the intermediate part bolts to this lower part. To permit the complete alignment of the upper and intermediate parts of the case the

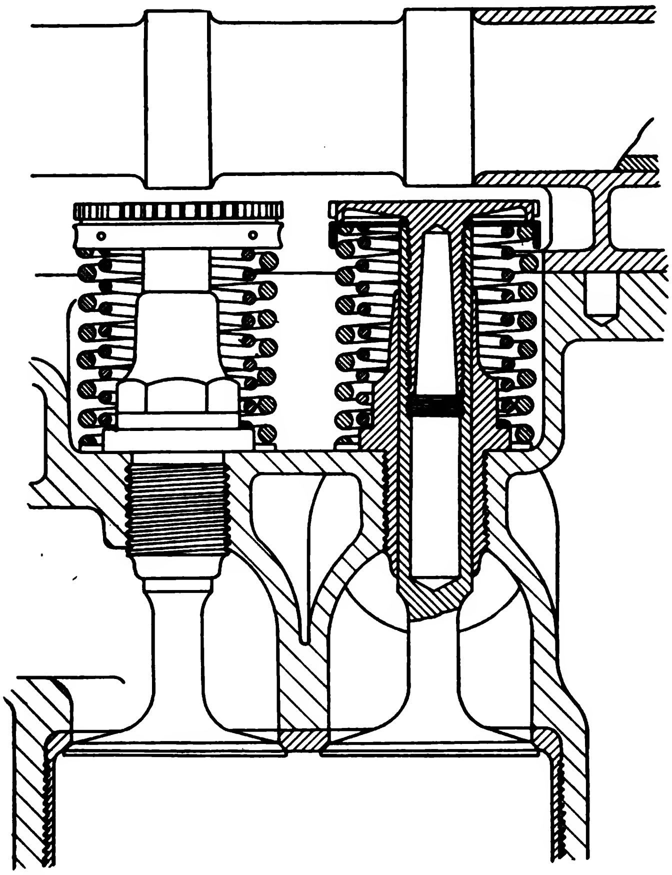


FIG. 10—ON THE HISPANO-SUIZA ENGINE A SPECIAL ARRANGEMENT FOR ADJUSTING THE VALVE CLEARANCE BY INSERTING A SCREW IN THE VALVE-STEM IS EMPLOYED

bolt-holes through the cylinder-base lugs *d* are made oblong. The endwise freedom of the connecting-rods on the piston pins permits of slight variations in the position of the cylinder-block on the crankcase. It is thus possible to adjust the mesh of both sets of gears and also the alignment of the two parts of the vertical shaft housing.

UNUSUAL FORMS OF CAMSHAFT DRIVE

We now come to a number of rather radical designs of overhead camshaft drives and overhead valve-actuating

FIG. 11 — SKETCH SHOWING THE RELATIVE POSITION OF VALVE OPERATING CAMS THAT ACT DIRECTLY ON FOLLOWERS SECURED TO THE END OF THE VALVE-STEM IN THE HISPANO-SUIZA ENGINE

mechanisms that have become known through recent patent publications. One of the cars that has attracted attention in the last year and a half is the Leyland eight-in-line. On the engine of this car an eccentric mechanism is used for transmitting motion from a half-speed shaft located close to the crankshaft and driven therefrom by a spur gear, to a short shaft normally in line with the camshaft. To obviate the difficulties due to the unequal expansion of the cylinder-block and the eccentric rods, the short shaft at the top has a support that is separate from the cylinder-head and is connected to the camshaft by an Oldham coupling which compensates for any slight misalignment between the driving and the driven members. The eccentrics are apparently set at angles of 120 deg. This drive ought to be commended from the standpoint of continuity. This construction is illustrated in Fig. 8.

A still more radical design of valve gear has recently been patented in England by the Fiat Co. Upon the upper part of the valve-stem is mounted a trunnion carrying two conical rollers. The trunnion is mounted between a shoulder on the valve-stem and a coiled spring that is backed up with a nut and lock nut at the top of the stem. Surrounding the valve-stem guide is a shell with opposite vertical slots through which the arms of the trunnion extend. On ball bearings upon this shell are mounted a pair of face cams upon the circumference of which are cut spur teeth. In the particular design

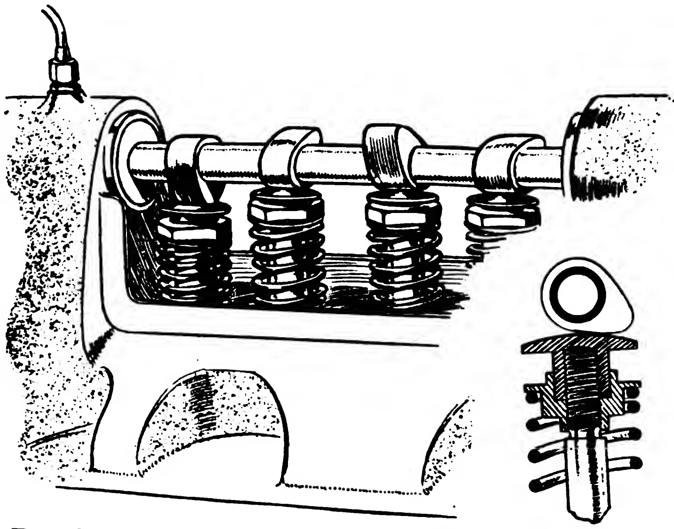


FIG. 12—CAM MECHANISM THAT WAS USED IN THE DAWSON, A BRITISH CAR THAT IS NO LONGER BUILT

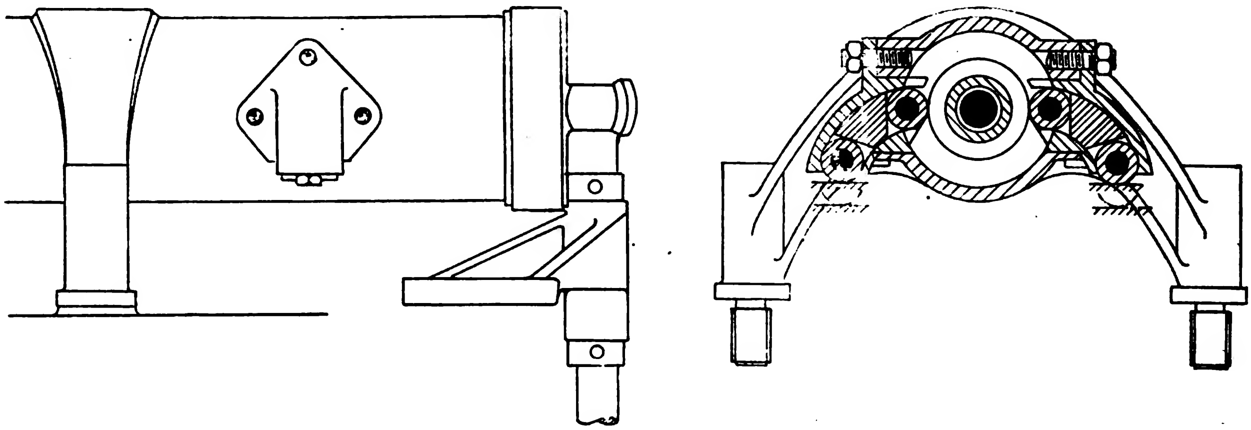


FIG. 13—THE BUGATTI OVERHEAD VALVE GEAR WHICH IS CHARACTERIZED BY CURVED QUADRANT-SHAPED PUSH-RODS WITH ROLLERS AT BOTH ENDS

shown in Fig. 9 there are four valves in the cylinder-head and all the cams are geared together. It is obvious that as the cams are revolved the valves are opened and closed positively, except for the slight play of the springs. A valve gear of this type should permit very high engine speeds, but the cost of manufacture is undoubtedly high.

VALVE MECHANISMS

At present three methods are in vogue for the operation of valves from overhead camshafts: The cams can act directly on cam followers secured to the end of the valve-stem, as in the Hispano-Suiza engine; single-armed levers or adjusting blades can be interposed between the cams and the valve stems; or the cams can act on the valves through the intermediary of tappet levers as in the Liberty aircraft engine. With the first-mentioned arrangement means for adjusting the valve clearance must be provided on the valve-stem itself. This problem was neatly solved by Birkigt, the designer of the Hispano engine. He drilled out the valve-stem and inserted a screw with a flat head with slotted rim. Underneath the screw head is a washer which has splines or keys on its inner circumference that engage into slots in the end of the drilled valve-stem, so that the washer can slide longitudinally on the valve-stem for a limited distance but cannot rotate with respect to it. The valve-spring presses the washer strongly against the screw head and the screw is thus locked. On the circumference of the washer there are several radial drill holes. A pin wrench is provided to engage into the holes and slots of the washer and screw head and permit the adjusting screw to be screwed farther into or out of the valve-stem. The details of this arrangement for adjusting the valve clearance are apparent from an inspection of Fig. 10, while the relative positions of the cams and the followers on the end of the valve-stems are brought out in Fig. 11.

Fig. 12 shows the system applied to the British Dawson car which is now no longer built. As will be seen, it resembles the Hispano in being of the direct-acting type and has similar means for the adjustment of valve-clearance. Despite the prevalent idea that Hispano claims a master patent on direct operation, Dawson continued to turn out engines with this type of valve system without serious interference for about two years. The failure of the firm was not ascribable in any way to the type of valve-gear used on the engines. The scope of the Birkigt Hispano patent apparently covers only the particular means of adjustment, including the pin wrench.

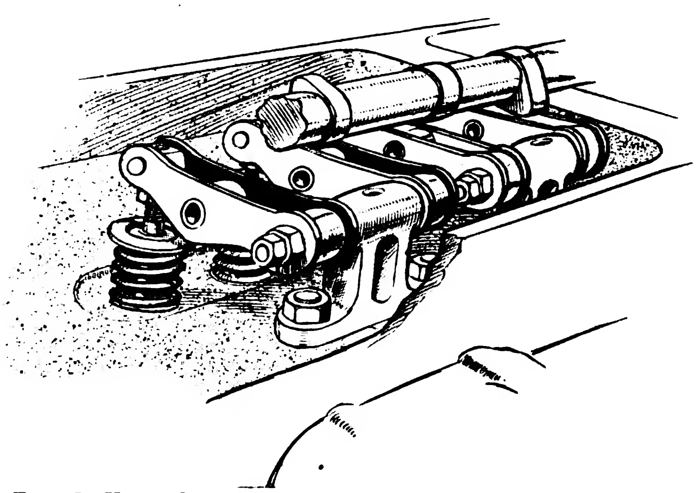


FIG. 15—VALVE OPERATING DETAILS OF THE 18-HP. FOUR-CYLINDER PHOENIX ENGINE

It is, of course, entirely possible to arrange overhead-valve mechanisms in a way similar to that used with the ordinary L-head engine. That is, between the valve and the camshaft can be placed a push-rod which is provided with an adjusting nut or adjusting screw and lock nut. The objection to this construction is that it makes the engine abnormally high. An overhead camshaft engine is much higher than an L-head engine in any case and if a push-rod is placed between the valves and the camshaft the height of the engine is increased by the length of the push-rod. There may be instances where this is of no

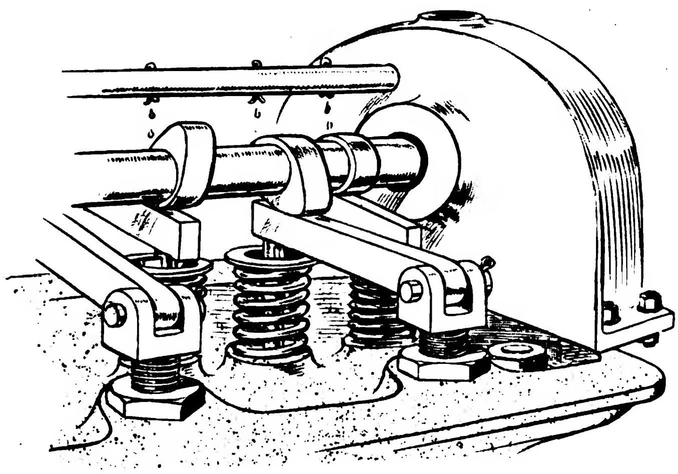


FIG. 14—CAM MECHANISM ON THE RHODE, A BRITISH LIGHT CAR HAVING A FOUR-CYLINDER ENGINE

great consequence as where a very small engine is placed under a normal sized hood, but in most cases it would be objectionable.

Bugatti developed an overhead valve gear which overcame this objection. He uses curved quadrant shaped push-rods with rollers at both ends. The cams on a camshaft placed centrally over the engine press against one of these rollers in a horizontal direction, while the other roller presses vertically down upon the valve-stem. The quadrant-shaped push-rods were located in guides bolted to the sides of the cylindrical camshaft housing with three bolts. The design illustrated in Fig. 13 is an early one, but the curved push-rod construction has been retained by Bugatti in a modified form. In this early design the provision for the adjustment of the clearance consisted apparently of the use of shims under the push-rod guide. Very frequently in recent designs the valves in the head are placed at an angle to the axis of the cylinder, one valve on each side of the central vertical plane of the engine, and the camshaft is then placed

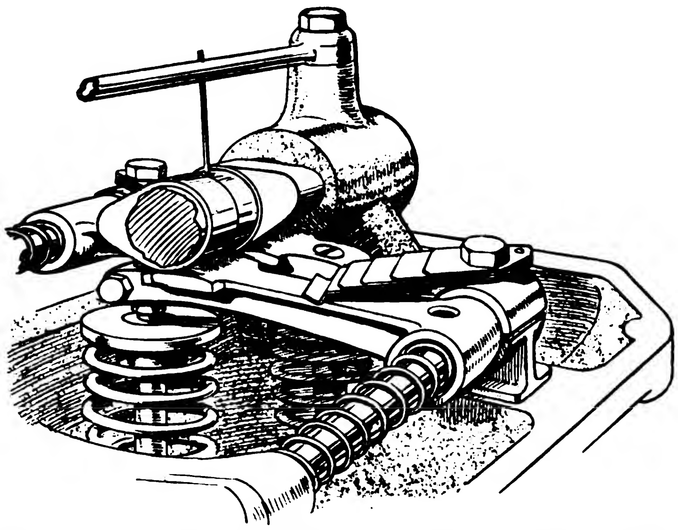


Fig. 16—The Beardmore Engine That Employs Pivoted Levers with an Offset Camshaft To Operate the Valves

centrally over the cylinder-heads; an arrangement which makes for symmetry. On smaller engines the plan of setting the valves at an angle is not so practical, for it calls either for a wide cover or makes it necessary to leave the valve-springs unprotected and have the tappet-levers extend through the walls of the cover. In aircraft engines this latter practice is widely followed, because

Fig. 18—The Overhead Cam Mechanism on the Straker-Squire Six-Cylinder Engine in Which the Valves on the Opposite Sides Are Outside the Camshaft Casing

dust and dirt are seldom factors to be considered in that line and the additional noise also is of no importance. In passenger-car engines vertical valves seem to be preferred and to make it possible to operate these valves from a central camshaft single-armed instead of double-armed tappet levers are used. The two valves are sometimes placed on opposite sides of the longitudinal central plane of the engine and are offset in the fore-and-aft direction sufficiently so that the two levers do not interfere. This arrangement permits the use of comparatively long lever arms that reduce the side pressure on the valve-stems and the enclosure of the entire mechanism in a compact housing.

One of the simplest, in fact crudest, overhead camshaft applications is that of the Rhode, which is shown in Fig. 14. This is a British light car with a four-cylinder engine of 67-cu. in. capacity, selling at a low price. Its camshaft, which is driven by a train of helical

Fig. 17—The Diatto Cam Mechanism (at the Left) That Employs Pivoted and Tapered Tongues Interposed Between the Cams and the Valves and (at the Right) the Overhead Camshaft of the Ansaldo Engine That Uses Rocking Levers with Bearings on a Shaft Immediately Above and Running Parallel to the Camshaft

FIG. 19—THE OVERHEAD CAMSHAFT GEAR OF THE LEYLAND EIGHT-CYLINDER-IN-LINE ENGINE

pinions, actuates the valves through levers of rectangular stock pivoted on adjustable standards screwed into the cylinder-head and provided with a lock nut. The camshaft is offset from the valve-stem and the clearance adjustment is made by varying the height of the pivot pin centers. This implies first removing the pins and then raising or lowering the standards in half turns, a means of adjustment which is not very precise. As the drawing indicates, individual oil drips from an oil pipe running from one to the other of the pressure-fed camshaft bearings are provided for the cams.

A British chassis of moderate price, with a four-cylinder engine of 180-cu. in. capacity having an overhead camshaft, is the 18-hp. Phoenix, of which the valve-operating details are shown in Fig. 15. This also has pivoted levers interposed between the valves and an offset camshaft, but the levers in this case are built up and somewhat resemble the links of a roller chain; in fact, the cam makes contact with a roller on the intermediate cross-pin. Provision for clearance adjustment consists of cap nuts on the valve-stems; the lubrication system includes pressure feed to the shaft bearings and separate drips onto the cams from a longitudinal pipe not shown in the illustration. The drive is by helical gears and a vertical shaft having a dog coupling that is provided with offset jaws to ensure correct reengagement within limits.

The Beardmore engine, illustrated in Fig. 16, also comes within the pivoted-lever class with an offset camshaft, though in this case the levers for inlet and exhaust-valves respectively are pivoted on opposite sides of the cylinder-heads. The lubrication details are similar to those of the Phoenix. Small leaf-springs prevent chattering of the levers. Pairs of levers are separated on their pivot shaft by helical springs that take up end play and allow the levers to be moved to one side to facilitate valve removal and clearance adjustment. The means for doing this consists of threaded studs in the lever ends that make contact with the valve-stems and are locked by a pinch bolt.

A design of distinct interest is that of the Diatto, which is shown in Fig. 17 at the left. This has pivoted and tapered tongues interposed between cams and valves, the camshaft center being immediately over the valve-stem centers. The clearance adjustment is effected by moving the tongue toward or away from the camshaft center-line, the horizontal supports being threaded, located in clearance holes and locked by nuts in the wall of the overhead valve-chamber as shown. Without being crude this is a simple design that should lend itself to economical production far better than many overhead camshaft arrangements. The angularity of the tongues must be large at full valve-openings and would be liable to result in undue side thrust on the valve-stems, but there appears to be no valid reason why the tongues should not be longer and pivoted farther away from the valves to reduce the angularity and the side thrust. With efficient lubrication the wear of the tongues should not be excessive. In any case they could be made easily and cheaply renewable.

Typical of many other overhead camshaft designs, the Italian Ansaldo shown in the right half of Fig. 17 is in the class embodying rocking levers with bearings on a shaft immediately above and running parallel to the camshaft from end to end, with the valves on opposite sides of the cylinder-head. The valves are usually, as in the Ansaldo, outwardly inclined at a slight angle from the vertical. Although in the case illustrated the clearance adjustments are on the valve-stems, set screws and pinch bolts in the outer ends of the rockers are more in favor.

The Straker Squire arrangement, illustrated in Fig. 18, is unusual in two respects: In the first place it is used on a six-cylinder engine with separate cylinders; in the second place the valves on opposite sides are outside the camshaft casing. The drawing is practically self-explanatory, except that it does not show that the camshaft casing is a unit casting running from end to end of the cylinders and secured to them by the studs and nuts that hold in place the individual cover-plates that bear the roller-ended rockers. The drive in this case is by bevel gears at each end of a vertical shaft.

Still more unconventional is the Leyland eight-cylinder-in-line overhead camshaft gear, illustrated in Fig. 19, the drive for which already has been described. Only one cam is used for the inlet and exhaust-valves of each cylinder, the cam acting upon slipper followers pivoted to built-up rockers. These at their outer ends bear upon T-pieces screwed into the hollow valve-stems, while the springs are semi-elliptic laminated units forked at their ends to engage with and exert a lifting pressure on the T-pieces and through them upon the valves. With a total disregard for the cost of production, the Leyland at £10,500 for the chassis is the most expensive British car, the designer having evidently aimed at securing silent operation by endeavoring to prevent valve-spring rebound and so adopted the laminated type. The pivoted slipper followers may also have appeared to hold out possibilities in the same direction, but by being satisfied with the compromise valve-opening diagram that is obviously necessitated by using the same cam for inlet and exhaust, he would seem to have nullified any gain in efficiency that might have been produced by the overhead valves.

Automatic Charging of Motive-Power Storage-Batteries

By H. M. Beck[1]

Mid-West Section Paper

Illustrated with Photographs and Diagrams

THE paper deals with storage batteries suitable for the propulsion of vehicles. The service required is much more arduous and such batteries are of a much heavier type than that needed for starting service.

The necessity of proper storage-battery charging is emphasized and the elementary principles of the storage-battery are reviewed, a description following of the evolution of the modern storage-battery and its development with regard to commercial production and safety from mechanical and other injuries. Illustrations of this modern type of battery are presented and its advantages and characteristics enumerated and commented upon at some length, inclusive of difficulties that have been met and largely overcome.

Methods of automatic charge-control and cut-off are discussed and charts presented to show the results obtained through use of automatic devices such as the ampere-hour meter. The two-step method of charge is described and various applications of the storage-battery to modern usage are mentioned.

THE title of this paper does not refer to starting batteries for internal-combustion engines. By motive-power storage-batteries we mean batteries used for the propulsion of any kind of vehicle. This includes batteries suitable for industrial trucks or tractors, the different kinds of storage-battery locomotive for use both in mines and for surface hauling and commercial street vehicles such as trucks and passenger-cars. The service required is much harder and the battery is of a much heavier type than is needed for starting an internal-combustion engine.

To be successful, a battery-propelled vehicle must be designed properly and be equipped with the correct type and size of battery but its success still depends absolutely upon the proper functioning of the battery. This seems to have been largely overlooked; at any rate, in the case of many battery-propelled vehicles very little attention has been paid to correct charging, upon which probably more than half of the success of the vehicle depends. Conditions vary in different types of service, and charging methods that are best for one type are not the best for another. After a very wide experience extending over many years, we have concluded that the full-automatic system of charging is the best and about the only practical one for motive-power service. We have tried the manual and the semi-automatic systems and find that there is no comparison with the full-automatic system in either the simplicity of maintenance or the results obtained. We do not expect any better results from the automatic system than we have obtained already from the manual in individual cases where the conditions happened to be right, but we do know from experience that with the former we can make the average results approach much more closely to the maximum.

The automatic charging of storage batteries is not a new idea; it has been used for many years in certain classes of service, but on a different basis. The practice has been to use it only where manual methods were impractical and to reproduce manual methods mechanically. The resultant apparatus is complicated and the service far from satisfactory. For example, automatic operation has been used for years for isolated gasoline-electric plants, and for steam-car lighting-equipment; more recently we have had the starting and lighting batteries on gasoline cars. The theory, however, has been largely to follow the manual method of charging at a constant rate, some automatic device being used to stop the charge at a specified voltage-limit. Although results of some value can be obtained, these methods are basically weak and on this account their use has been limited.

About 10 years ago we brought out a steam-car lighting-system that was fundamentally different from the rest. Instead of using a constant current with a voltage cut-off, we reversed the operation and applied a rather low constant voltage. This gives a taper charge due to the rise in the battery voltage as the charge progresses and the current tapers down almost to zero when the battery is fully charged. This system is one of the best examples of automatic charging to-day. It remains almost unchanged and produces excellent results but, unfortunately, its field of usefulness is somewhat limited.

The Pullman Co. brought out an improvement a few years later. This involved using its old car-lighting system and approximately a constant-current charge automatically controlled, and applying an ampere-hour meter cut-off in place of a fixed voltage cut-off. The system requires some adjustment and is complicated but, where the conditions are favorable, it approaches closely the results obtained from the constant-voltage system.

With the rapid growth of industrial electric trucks and locomotives a demand was created for the elimination of the charging problem, chiefly because of the class of labor involved. A thorough study of the problem was made and a system was laid out based on the inherent control characteristics of the storage battery, using the best experience of previous practice. It was found that not only a system, but equipment as well had to be developed. For example, although the ampere-hour meter was on the market, it was far from its present development. Suitable charging plugs, resistances and circuit-breakers were not available. The development has now reached a stage where we can cite actual practice.

Our automatic charge-control system has been in service in large fleets for approximately 4 years and has exceeded our expectations. We are no longer recommending the automatic system simply as a substitute for manual operation where that is not practicable, but rather in place of it because, through its use, we can obtain results that we have been unable to obtain in any other way. For example; the first battery that went out with the constant-voltage car-lighting system is still in operation after over 8 years of service. We can say

[1] M.S.A.E.—Engineer, operating department, Electric Storage Battery Co., Chicago.

that the plates could not have been in better condition if they had been operated under the best manual control. One of our first motive-power installations was in connection with two industrial-truck batteries, charged at night and cut-off by a night watchman when he happened to remember it. The result was that one battery was practically burned up within 6 months. We then installed the automatic system. This fleet now consists of nine trucks; the original batteries have been in use for 3½ years and are still giving good service. We installed a large fleet of electric locomotives equipped with what might be called a semi-automatic system. An automatic charge cut-off was provided, but the charging current was under hand control. Within less than a year we experienced trouble. The men supervising the battery charging were given overtime to complete the charge, whether that time was required or not. They found that by raising the rate the batteries became charged more quickly and they could get home that much sooner. The consequence was that the batteries were sadly overheated, with resulting injury. Arrangements were then made for automatic rate control as well as automatic cut-off. The battery temperature dropped 15 deg. in 1 month. Heat is one of the worst enemies of the storage-battery. These instances should give some idea of what the full-automatic system will accomplish and why we consider it the only practical system for this class of service.

Storage-Battery Principles

It will be easier to explain the development of the full-automatic charging-system if we first scan some of the general principles of the storage-battery. The first question that arises is why we use a storage-battery for the propulsion of vehicles instead of some other means. The storage-battery is one the simplest as well as most reliable pieces of apparatus available. Its very reliability is one of its weaknesses. The fact that a battery will operate for long periods after it needs attention results in its being often neglected until it is permanently injured. Most people think of a storage battery as being heavy, whereas, from an energy storage standpoint, it is relatively very light. A rubber band will store sufficient energy to lift its own weight 300 ft.; and a steel spring about 500 ft. Compressed air, at 1000-lb. per sq. in. pressure, will lift its own weight, including the weight of the steel tanks, some 7000 ft.; whereas a storage battery will lift its own weight nearly 5 miles, about 3½ times the lift of its nearest competitor.

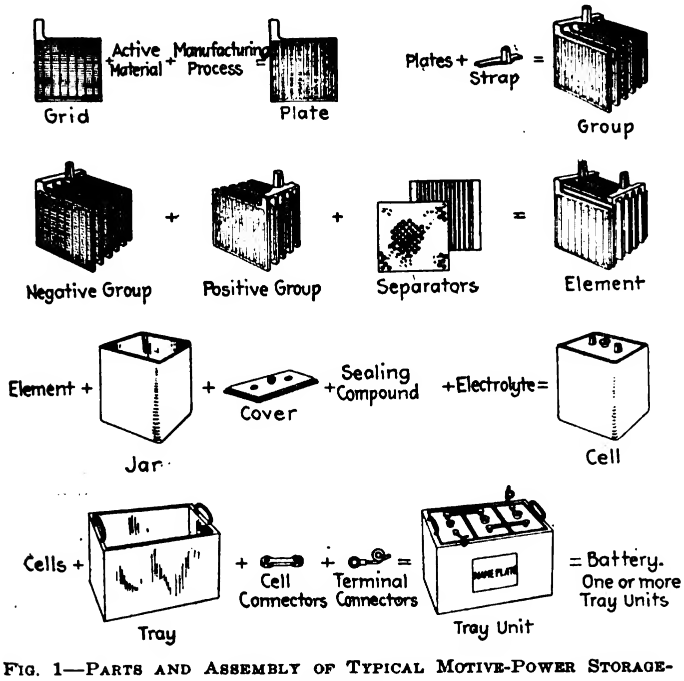


Fig. 1—Parts and Assembly of Typical Motive-Power Storage-Battery

The storage battery was discovered by accident. About 1860 a Frenchman named Planté, while investigating the principles of electrolytic cells, submerged two strips of lead in a dilute solution of sulphuric acid and water and passed an electric current through them from an outside source. The two ends of the circuit accidently came together and he noticed that a meter in the circuit gave a reverse deflection, this indicating a discharge, and that he was getting back some of the current that had been put into the cell. He realized at once that he had discovered a means for storing electricity and from this simple model, unchanged in principle, we have the storage-battery of to-day.

The reason for the storage ability of this simple model is not difficult to state. Chemistry teaches that energy is always either released or absorbed when different elements combine, and that when the conditions are favorable this energy can be made to show itself in the form of an electric current. In Planté's cell we have two elements, sulphuric acid and lead. During discharge these combine, forming a salt of lead known as sulphate of lead. During charge, the lead sulphate is broken up, the acid is returned to the solution and the lead is brought back to its original condition. It should be noted that in this cycle nothing is lost, none of the chemical elements are used up and therefore nothing need be replaced. There is a general idea that the acid in a cell is used up during charge and discharge and must be replaced. During discharge, the elements combine and form lead sulphate and this combination releases energy in the form of an electrical current, but during charge the process is completely reversed, the combination is broken up and all of the acid is restored to the solution.

The Modern Storage-Battery

The modern storage-battery is not so simple as Planté's two pieces of lead immersed in a dilute solution of sulphuric acid and water, but the principle is identically the same and the development has been almost wholly mechanical. Fig. 1 shows the parts and assembly of a typical battery. A plate consists of a grid cast from lead alloy which acts as a mechanical holder for the finely divided lead that constitutes the active material. To obtain capacity the surface area of the plate must be large. We could accomplish this by simply making the plate very large, but it would soon become too big to handle conveniently; so we cut it into a number of sections and weld them to a cross-bar. This forms a group that is really a large plate cut into sections, acting otherwise as a single large plate. A positive group and a negative group assembled with separators for spacing and insulating the plates constitute a complete element. An element, a jar and cover, the sealing compound and the electrolyte form a complete cell; one or more cells, cell connections, terminal connections and trays constitute a complete battery.

The Ironclad positive plate which we are using in motive-power service is shown at the left of Fig. 2. In principle it is identical with a simple strip of lead, but it has been developed mechanically so that it will give far better service. The plate consists of a number of tubes joined by a metal bar at the top and bottom. The

tubes are made of hard rubber and are slotted or laminated horizontally to allow the electrolyte to circulate through the wall to the finely divided lead or active material with which they are filled. The finely divided lead surrounds a core of lead alloy that acts as the conductor. This plate is based originally upon a French design. The French plate, however, was impractical from a manufacturing standpoint and it has taken many years to develop the plate commercially. This design results in a maximum surface since the entire surface of the cylinders is exposed to the electrolyte and the rubber sheathing holds the active material in place. This greatly increases the life of the plate, which is roughly from two to three times that of the unprotected plate. The capacity also is greater and, due to its protection and rugged construction, this plate will withstand considerably more abuse than an equivalent flat plate. These characteristics indicate the selection of this plate for motive-power service, as the conditions are apt to be very severe.

Fig. 2—At the Left the Positive Plate for a Motive-Power Storage-Battery; In the Center a Negative Plate and at the Right a Complete Cell

A negative plate, such as is shown in the center of Fig. 2, is not subject to the same action as a positive, and so does not require the same protection. On this account a flat plate has been selected and found perfectly practical for this cell. The two small feet at the bottom, also seen in the complete cell at the right, deserve attention. As will be noticed, the plates are supported on four bridges. The feet of the negative plates are offset as compared with the feet of the positive plates so that the negative plates rest on two of the bridges and the positive plates on the other two bridges. Thus, the positive and the negative plates do not rest on the same bridges and sediment collecting on top of the bridges can join only plates of like polarity and will not short-circuit the cell. These feet also permit the use of a thin wooden diaphragm, not over 1/16 in. thick and longer than the plates, as a separator. This prevents bridging of the material between the plates at the bottom, a trouble that sometimes occurs in the old construction.

In the early days of motive-power service, especially in mine locomotives where the mechanical conditions are probably more severe than in any other type of service, we had a great amount of jar breakage. This resulted in the development of the special so-called giant jar which is practically unbreakable in normal use. It was first used in mine locomotives but has since been adopted for nearly all types of motive-power service.

The two problems to be solved in automatic charging

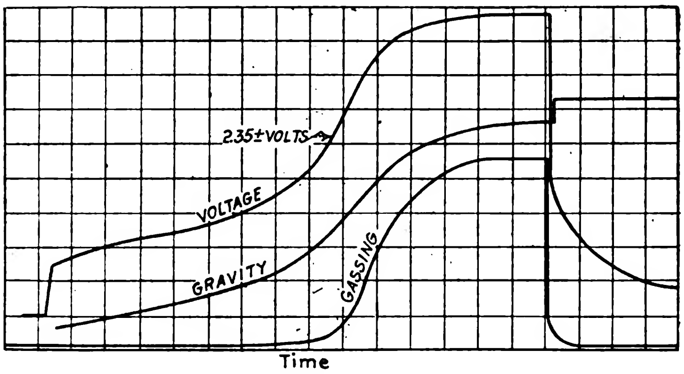


Fig. 3—Three Characteristic Curves Indicating the Voltage, Specific Gravity and Gassing of a Storage-Battery During Normal Charging at a Constant Rate

are, first, the control of the charging rate and, second, the cut-off. Neither one alone solves the problem and experience has shown that the full-automatic system is the only safe one for motive-power service. The rule for determining the proper charging rate is simple. As I have explained, we must avoid gassing and heating. These effects are closely related and if we avoid one we are apt to escape the other. Any system that avoids gassing and heating is safe so far as the battery is concerned, no matter how high or how low the charging current is.

Fig. 3 shows three characteristic curves, indicating the behavior of the voltage, specific gravity and gassing, during a normal charge at a constant rate. As will be noted, the voltage gradually increases as the charge progresses; toward the end the curve rises sharply, then bends over and finally reaches a maximum beyond which it will show no further increase no matter how long the charge is kept on. This maximum indicates the state of complete charge. The specific gravity behaves very much in the same manner. Gassing is very slight during the major part of the charge; there is a burst of gas near the end of the charge; the curve then tends to flatten out and reach a maximum. An interesting feature of the gassing curve, bearing on automatic control, is the fact that gassing in any considerable quantity is not shown below 2.35 volts per cell. From these curves we can deduce the following general principles. The voltage of a cell rises during charge and to charge at a constant current it is necessary to increase the applied voltage

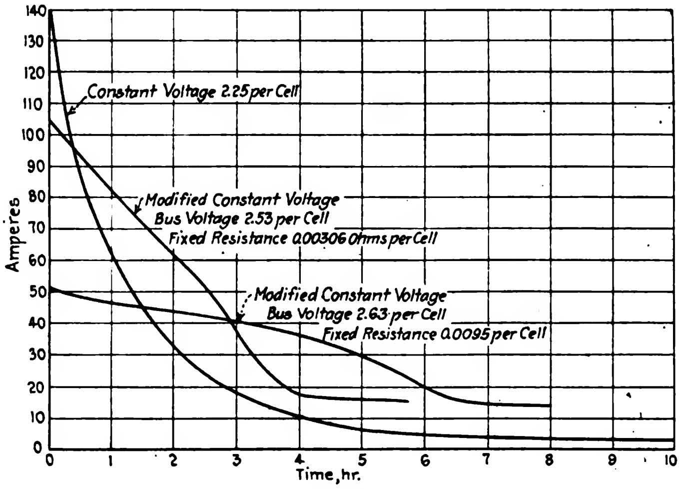


Fig. 4—Curves Illustrating Different Characteristics Resulting from the Application of a Constant Voltage to a Discharged Battery With or Without a Fixed Series Resistance

gradually. Conversely, if a fixed voltage is applied the current will taper and gradually become less as the charge progresses and, if the voltage applied does not exceed 2.35 per cell, there is no serious danger from gassing or heating.

Fig. 4 shows curves illustrating different characteristics resulting from the application of a constant voltage to a discharged battery, with or without a fixed series resistance. Depending upon whether the fixed resistance is used or not, this system is known as the modified constant voltage, or the constant-voltage system. The first curve illustrates the application of a constant voltage of 2.25 per cell without series resistance, and this comes under the constant-voltage classification. It also represents the combination used in the case of the constant-voltage car-lighting system already mentioned. As will be seen, even at this voltage, which is considerably below that of the gassing point, 2.35 volts, the current starts at an extremely high value and then tapers rapidly to a very low value. It is due to this very low final current that no charge cut-off is required in the car-lighting system. The current starts at two or three times the normal rate if the battery is fully discharged, and tapers down to about 5 per cent of the normal rate when the battery is charged. While this particular system requires no cut-off, it is limited in its application because considerable time is required for a complete charge, on account of the low charging-rate during the latter part of the charge, and this time is too great for motive-power service. In car-lighting service, however, the conditions are different and this does not constitute very serious objection. In the case of a fleet of trucks the high starting rate is objectionable on account of the load factor. Therefore, to obtain a practical charging system, we must find some means to reduce the high starting-rate and raise the low finishing rate. We can raise the low finishing-rate by increasing the applied voltage. This will of course increase the already high starting-current, but this can be reduced by introducing a very low series resistance into the circuit; this resistance will be so low that it will have practically no effect upon the finishing rate. We thus have the so-called modified constant-voltage system.

The second curve, Fig. 4, is obtained by applying a

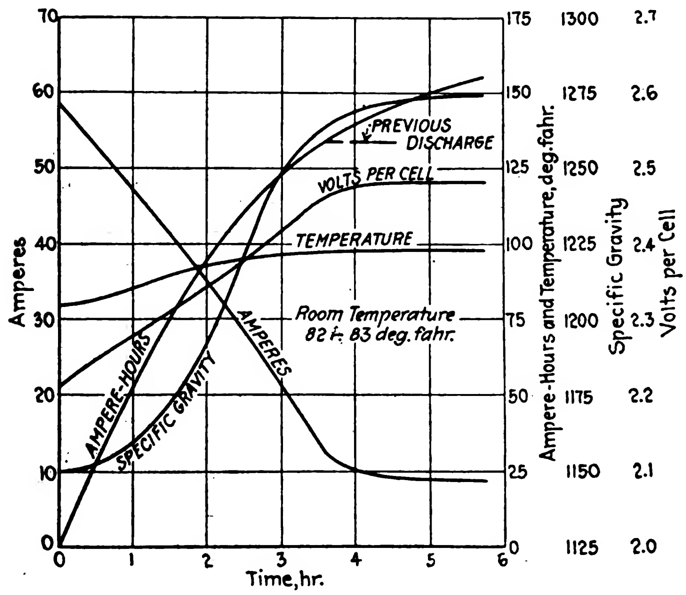


FIG. 5—CURVES OF ACTUAL READINGS TAKEN DURING A QUICK CHARGE REQUIRING ABOUT 5 HR.

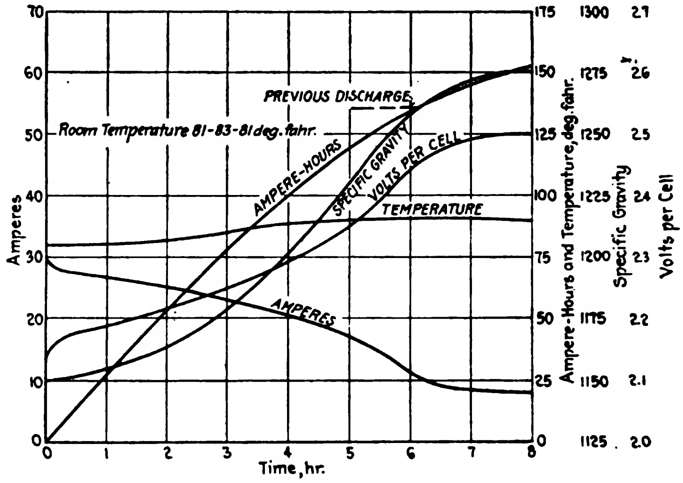


FIG. 6—CURVES OF ACTUAL READINGS TAKEN DURING A SLOWER CHARGE REQUIRING APPROXIMATELY 8 HR.

voltage of 2.53 with a series resistance of about 0.00306 ohm per cell. As is shown the current now starts at a lower point, holds up much more steadily, finishes at a higher point and the charge is completed in about 5 hr. under perfectly safe conditions; in fact, in the case of one fleet of locomotives that has been in service more than 2 years, only 4 hr. is available for the charge on account of the arrangement of shifts and, while this is an extreme case, it is being handled automatically.

The third curve, Fig. 4, shows the results obtained from a higher applied voltage, 2.63, and a higher series resistance of 0.0095 ohm. The curve starts at a still lower current value, ends at the finishing rate and the charging time is increased to 8 hr. It will thus be seen that with this simple system, depending upon the inherent characteristics of the cell, we can obtain automatically almost any value of charging current. This is the basis of our whole system so far as the rate control is concerned.

The curves in Figs. 5 and 6 show actual readings taken during charge, the first representing a quick charge requiring about 5 hr. and the other a slower charge requiring about 8 hr., together with the voltage and fixed resistances used in each case.

Another method of arriving at this same result is to design a generator with the proper characteristic to give battery-voltage and current curves similar to those shown in Figs. 5 and 6. We then get the same current characteristic without the use of the series resistance. This is the basis of the small motor-generator charging outfits with inherent taper-current characteristics that are so largely used. The proper characteristic is obtained either through a rather large armature reaction in the case of a shunt generator or by the use of an inverted series field, so, the voltage increases slightly as the load on the machine decreases. These motor-generator sets are applicable only to charging one battery, or two at the most, since a generator cannot be designed with the proper characteristic for simultaneously charging several batteries in different states of discharge. On this account the modified constant-voltage system generally is used for large fleets.

METHODS OF CUT-OFF

The question of the automatic-charge cut-off is not so simple. Fig. 7 shows curves giving the voltage and gravity characteristics during a constant-current charge. As already explained, the voltage curve rises gradually

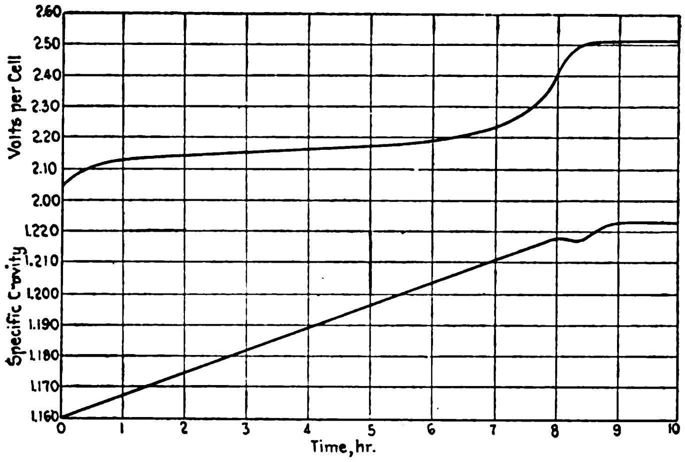


FIG. 7—VOLTAGE AND GRAVITY CHARACTERISTIC CURVES OF A STORAGE-BATTERY DURING CHARGING AT A CONSTANT CURRENT

during the bulk of the charge, much more rapidly just at the end and then bends over and reaches a maximum, which is the voltage indication of the full charge. The voltage was one of the first means employed as an automatic cut-off, but it is a difficult problem and has never been very successful. Any apparatus for showing when a maximum voltage is reached is complicated and would hardly be practicable in regular service. The actual voltage at which the cell is charged varies through wide limits. At high temperatures, the maximum reading may not reach 2.4 volts, whereas at extremely low temperature it has been known to go above 3.0 volts. There is no fixed voltage that will indicate when a battery is charged under varying temperatures. Further, the voltage depends directly upon the charging rate. If the charging current varies, the final voltage will vary. Finally, it depends upon the age of the cell and the strength of the electrolyte, and so many allowances are required that it has proved far from successful. The voltage cut-off has been used on a large scale in car lighting, but the so-called stop charges have been eliminated frequently because in many cases they interfered with rather than helped the operation.

The specific-gravity reading rises during charge much the same as the voltage and therefore can be used to cut-off the charge. This method has been employed in some types of stationary service, but it is decidedly difficult to get an accurate specific-gravity reading in motive-power assemblies, so that this method is almost out of the question for this service. The specific-gravity cut-off has most of the objections that apply to the voltage cut-off, its only advantage being that it is not so seriously affected by the charging rate.

The specific-gravity curve, Fig. 7, shows a slight irregularity near the end. This was formerly attributed to inaccuracy in the readings but, when recording hydrometers were developed, they showed it to be a regular characteristic. It is due to the rapid increase in the amount of gassing which occurs at this point. The combination of gas and electrolyte is lighter than solid electrolyte; so, the specific-gravity rise will be checked temporarily.

The ampere-hour efficiency of the cell is one of its most uniform characteristics. If 100 amp. hr. is taken out of a battery of given size, a close estimate can be made as to how many ampere-hours will be needed to charge it. This ratio is called the percentage of overcharge. It is not subject to many of the variations which apply to voltage or specific gravity and, within a small percentage, it is independent of temperature, the age of the battery or the charge and discharge rates.

THE AMPERE-HOUR METER

The ampere-hour-efficiency method depends upon some instrument for measuring the output and input in terms of ampere-hours. The ampere-hour meter is such an instrument. This is the instrument already mentioned as having been applied to the cars of the Pullman Co., and a decided improvement resulting. In fact, the addition of the ampere-hour meter has been responsible to a large extent for more than doubling the life of the batteries in this installation. The ampere-hour meter is shown in Fig. 8 at the left. It is simply a quantity meter and measures the product of current and time, or ampere-hours. The pointer moves clockwise when the current flows in one direction, and counterclockwise when the current flows in the opposite direction, thus registering charge and discharge. Further, it is designed so that it can be made to run at any given percentage slower in one direction than in the other. Hence, when the pointer gets back to zero it is indicated that a fixed percentage of overcharge has been put into the battery and that the charge is complete. The meters are equipped with a contact at zero that permits opening a shunt trip circuit-breaker and cutting off the charge when the zero point is reached. In other words, with this combination we have an automatic charge cut-off based upon the ampere-hour-efficiency principle which has proved the best if not the only practical method to date.

We have encountered prejudice against the use of ampere-hour meters, much of it being founded upon mistaken ideas. For example, there are several different grades or sizes of ampere-hour meter and the small cheaper type will not withstand motive-power service. In a very large percentage of cases where we trace the prejudice against ampere-hour meters we find it based upon trouble that resulted from the use of the wrong meter. An ampere-hour meter is a maintenance proposition. To take the position that because an ampere-hour meter fails it will not withstand the service, is not logical. An ampere-hour meter probably requires very much less maintenance than any other part of the equipment; this has been proved on a large scale. It does require some maintenance but is well worth this. One fleet of trucks in Chicago using about 80 of these meters sends in two or three meters per month for adjustment,

FIG. 8—AT THE LEFT AN AMPERE-HOUR METER AND AT THE RIGHT A SHUNT-TRIP CIRCUIT-BREAKER

cleaning and overhauling. This means that each meter has an overhauling every 2½ years on the average. The Pullman Co. has several thousand meters. Their records during 1 month showed 1 failure in 800 departures, which is a fairly close approximation of the truck record.

In the early days, even when the right type of meter was used, it was the practice to install one entirely too large. Any electric meter has a tendency to run slow at low loads and this meter is no exception. It will run 2 per cent slow at 10 per cent of its rated load; below this, it falls off rapidly. Meters twice as large as should have been used were installed in many cases. This meant that the finishing rate of charge went below the range of accuracy; the meters ran slow and overcharged the batteries. The meters should not be blamed for what was simply poor engineering. We are now recommending the exact size of meter to be used in each case; we would much rather risk a burn-out than use too large a meter, and there are very few burn-outs.

Auxiliary apparatus has given trouble and this has been attributed to the meters. For example, when circuit-breakers that require too much current to release or are unreliable have been used, the zero contact mechanism has burned out and the meter blamed. A number of meters were recently reported in trouble, and in every case the cause was a broken wire in the plug cable. A solid instead of a flexible wire had been used and naturally broke after comparatively few bendings. These cases are cited to show the reason for much of the prejudice against this meter. Much of it is illogical but, on the other hand, the meter was far from perfect. The manufacturer, however, has cooperated in improving it so that today we have a different meter from the one we had even 2 or 3 years ago. For example, the meters are now dust and waterproof and it is claimed that they will operate under water. The old meters were neither dust nor waterproof and naturally gave trouble on this score. The overload capacity has been increased recently to 300 per cent of the rating, which allows the use of a much smaller meter. The aging factor or tendency to run slow has been reduced. The result is that there are fewer chances of failure with the present meter and with reasonable maintenance it will

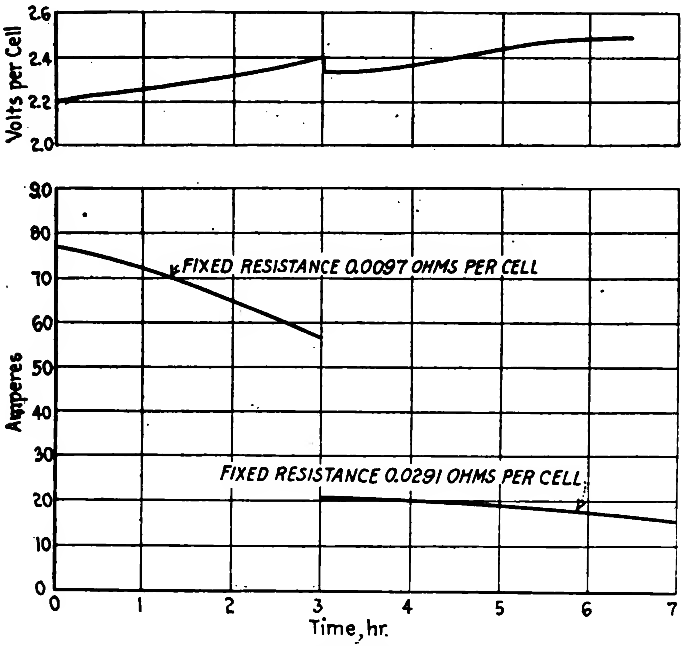


Fig. 9—Characteristic Curves Obtained During a Two-Step Charge of a Storage Battery

Fig. 10—A Special Automatic Switch That Has Been Developed for Use in Connection with the Two-Step Charge

give service that we have not been able to produce in any other way. It is the only satisfactory automatic storage-battery cut-off of which we know.

The view at the right of Fig. 8 shows a shunt trip circuit-breaker that has been developed for use with these ampere-hour meters. It is of the hand-closing type and simply opens the circuit when the meter reaches zero; it also has been improved considerably within the past few years.

The Two-Step Charge

So far, in developing the automatic system, it has been assumed that a constant voltage could be selected that would produce the character of taper charge desired, but there are many cases where this cannot be controlled. Charging is often done with commercial voltages that are not what is wanted. Odd sizes of battery, such as 12, 16, 18, 24 or 30 cells are used, especially in industrial trucks, which do not fit the usual voltages. To meet this condition another system of charging which is somewhat more complicated has been developed. It is known as the two-step charge. Characteristic curves are shown in Fig. 9. In this system we start with a fixed series resistance of the proper size to give the desired current-rate and continue to a point which on an ampere-hour-input basis corresponds with the gassing point. The ampere-hour meter is equipped with a second contact which opens at this point. This opens a small self-closing circuit-breaker that shunts some part of the resistance. Additional resistance is thus cut into the circuit and the charge finished at a reduced rate. Such rate reduction can be accomplished in several ways but, where the ampere-hour meter is already installed, it might just as well be used for the rate-reducing function as well as the cut-off, so that this method has been selected for general use.

It should be noted that when the gassing point is reached the ampere-hour meter opens and does not close a circuit. This is an illustration of a characteristic that should be incorporated in any automatic system and, so far as possible, provision should be made so that if part of the apparatus fails no serious injury will result. By opening the controlling circuit instead of making it, chances of a poor contact are avoided. For example, supposing that we were to depend upon making a contact for reducing the rate, the charge would be finished at the high rate in case of a contact failure. This would overheat the battery and possibly burn it up; whereas, working the other way, if that contact is not made, it simply means that we start the charge at the low rate and, while it will require a longer time to charge, no injury to the battery will result. As another illustration, if the cut-off does not operate, nothing serious happens. The final current-rate with either system is so low that the battery could be charged for hours without causing any serious injury. We do not recommend continuing

the charge in this manner as a regular practice but, should the cut-off fail to operate occasionally, no serious injury would result.

Fig. 10 shows a special automatic switch that has been developed for the two-step charge. When the extra contact is closed, the shunt coil is energized, the circuit-breaker automatically closed and the charge starts at the high rate; or, if the meter pointer is not far enough around to close the contact, the charge starts at the finishing rate. This switch does not require manual attention but works automatically in conjunction with the ampere-hour meter. One size of breaker covers practically the entire field. It has a capacity of 100 amp., which covers nearly every case and, by shifting the connections, it can be used on either a 250 or a 125-volt circuit. Although it requires only a few hundredths of an ampere to hold it closed, the pull is so strong that it is difficult to open the switch with one hand.

While not directly pertaining to automatic charging, the ampere-hour meter has another feature that is almost as important as the charge cut-off; namely, protection against overdischarge. The dial is equipped with a red empty hand that indicates the capacity of the battery, so that the operator of the vehicle knows at any time how far the battery is discharged and what additional capacity is available. This one feature has gone a long way toward eliminating overdischarge. When a battery is overdischarged, it becomes somewhat less efficient due to the abnormal sulphation, and requires a special charge. Thus, proper charging depends upon proper discharging, and proper charging for normal conditions may be wrong charging if an overdischarge has occurred. The empty hand is normally set at about 90 per cent of the battery rating to provide some leeway and permit getting home in case the limit is reached on the road. This one feature, protection against overdischarge, is considered so vital by one mining company that the empty hand has been changed to a contact. If a motorman reaches the limit, a circuit-breaker opens and renders the locomotive inoperative. The circuit-breaker is locked and the motorman has to send for the key before he can move, so he is not apt to allow this to happen very often.

THE DISCUSSION

CHARLES H. ROTH:—How does the automobile charge-control system work out in farm lighting-battery charging, using the ampere-hour meter?

H. M. BECK:—The ampere-hour meter is probably the best device for farm lighting-plants but it is not as well suited to this service as it is to motive-power work. The farm lighting-plant loads become so low at night, when using single night-lights for instance, that the ampere-hour meter does not record the discharge. The result is that part of the load is not recorded and the battery is not really charged when the meter indicates charge. We call this getting out of step. It means that there will be a battery failure sooner or later. The ampere-hour meter has not yet been developed so that it can be thoroughly depended upon for stationary service. I have a sample meter now that I expect to test very shortly, and of which I am hopeful. It is not a mercury-type meter, but of the commutator type. It has a wider range, but unfortunately will not withstand the vibration of the motive-power service.

MR. ROTH:—Are you simply waiting for a perfect auxiliary device?

MR. BECK:—When we get a device that is suitable for the stationary plant, we will certainly push it.

G. T. BRIGGS:—How does the battery withstand tractor work, when using it for night work?

MR. BECK:—That is rather severe service. We developed a battery that will withstand it. We have installed it in a number of tractors but the field has developed slowly. The battery has a number of features. We subject the cell to a bumping test, and it actually withstands millions of bumps that will put the ordinary automobile storage-battery cell out of service in from 3 to 5 hr., as the plates cut right through the bridges and the bottom of the jar; but that tractor cell will come through in perfect shape with only a small indentation in the top of the rib. The top of the supporting bridge is made of soft rubber so that it cushions the plate. The sealing and sealing nuts are special and the jars are extra heavy. So far as I know, only two tractors in general use have adopted the battery as standard equipment.

H. L. HORNING:—We have discouraged the application of engine-starter equipment to trucks, not because we thought the storage-battery was not good enough but on account of the amount of trouble in making the engines ready to connect the generator. That attitude is simply the result of practical considerations in manufacture. In connection with motor trucks, there is no doubt that a suitable electric lighting system is becoming a necessity; the motor truck cannot fulfill its place in the transportation system without one. At present it is difficult to persuade anyone to use a battery system on tractors. There is some feeling against the use of a battery system for ignition on the motor truck, although the objection is not so strong as in the case of the tractor. I have confidence in the manufacturers of batteries and electric systems and believe that they can overcome the difficulties if they are given the opportunity. The practical considerations of operating and maintaining batteries in the country and the unfamiliarity of the public with storage-batteries have retarded their adoption. The time is coming when generator-charging outfits will be demanded.

R. B. HALL:—What is the average life of a storage-battery on industrial trucks, provided it is charged properly by the automatic system.

MR. BECK:—I referred to one battery that has been in straight industrial truck service for 3½ years and still operates well. The length of life of a battery depends not only upon the care it receives but also upon the amount of work it does. In lightly worked trucks the battery lasts much longer. Yard-locomotive work is light service. We have a battery that has been in such service 10 years. I have a battery in my own car that is more than 8 years old but the service is fairly light. We eliminate the charging problem with the automatic charging system; so the matter is largely one of how much work the truck does. The older batteries have a 1¾-in. sediment space. We now allow for about 2½-in. of sediment. The industrial-truck batteries that I mentioned are depositing sediment at the rate of about 5/16-in. per year; it is evident that the Ironclad battery has a long life. The results with the flat-plate battery are not so good. The Ironclad plate should last from two to three times the life of the flat-plate. We estimate that the flat plate will withstand 300 to 400 complete discharges and that the Ironclad plate will withstand about 1000.

MR. ROTH:—Is not 10 years a remarkable length of battery life for motive-power service?

MR. BECK:—It is better than the average.

MR. ROTH:—What is the life of batteries under the

worst and the best conditions? I understand that starting and lighting batteries are short-lived.

MR. BECK:—On the basis of the batteries renewed by one of our depots during 1 year, the average battery life was about 3 years. By automatic methods we hope to bring the average life closer to the maximum.

MR. ROTH:—A man who manufactures storage-batteries told me several years ago that the average life of a storage battery on an automobile, for starting and lighting purposes, is about 11 months.

MR. BECK:—The life of starting and lighting batteries is usually stated to be 18 months. The last statistics on this type that I have seen averaged a period of somewhat more than 2 years. The heavier type of starting battery will average from 4 to 7 years, but on account of its weight, size and cost, it is not used generally.

TALIAFERRO MILTON:—The New York statistics for all the batteries for last year show that the average battery-life, including 7 months' minimum life, was 38 and the maximum 55 months; many of them had a life of more than 40 months.

M. SCHIFF:—With reference to the industrial application of batteries for propulsion purposes, you mentioned that there might be a considerable diversity of battery sizes. How is the automatic feature carried out under such a condition?

MR. BECK:—Using the taper charge, the fixed voltage is the same no matter what the size of the battery is; it depends only on the number of cells. The series resistance varies with the size of the battery. For example, suppose we have a street truck having the proper number of cells for a 110-volt charging system and desire to arrange for such a charging system. We would install a resistance in series with the charging socket on the vehicle, figured for that particular size of battery. If the equipment is connected to a 110-volt system, the desired amount of current is obtained automatically.

MR. SCHIFF:—Do you use the constant-potential method of charging only in that particular application?

MR. BECK:—We use what we call the modified potential in that particular application.

MR. SCHIFF:—I understand that the ampere-hour meter is not used in that instance.

MR. BECK:—No, it is used only as a cut-off in that arrangement. As a means of rate control, the ampere-hour meter comes in only where we cannot control the voltage. There are many situations where we cannot get the voltage we want. In that case we use the two-step charge, which is controlled by the ampere hour meter. Where we can control the voltage, we much prefer the straight modified constant-potential system. When necessary, we can charge more quickly with the straight modified system. The best we can do safely with the two-step system is to charge in about 7 or 8 hr., but we can charge in 4 or 5 hr. with the modified system.

MR. HALL:—What is the effect of charging with the cercury-arc rectifier instead of a generator? Is it possible to use that with the automatic system?

MR. BECK:—The question of using the mercury arc is entirely one of the rectifier characteristic. The rectifier can be designed, but the minimum current limit is fixed. If the desired minimum is not too low, the rectifier affords a satisfactory charging system.

MR. SCHIFF:—In using the ampere-hour meter to control the charge, how is the charge affected at temperatures near freezing or below?

MR. BECK:—The ampere-hour efficiency is almost independent of the temperature. That is one reason this system has gained ground so rapidly. The number of watts is not independent of the temperature; that is, the charging voltage is much higher at low temperatures. If we were using a wattmeter, more watts would be needed when charging at low temperatures, but the ampere-hour efficiency is almost constant. At high temperatures the internal losses in a battery are somewhat increased. Where the amount of discharge is light, the internal losses may become an appreciable percentage, but in ordinary service we use standard fixed percentages of overcharge.

MR. SCHIFF:—What I wished to bring out is that the ampere output is actually very much lower.

MR. BECK:—An appreciable time must elapse before outside temperatures affect the commercial vehicle to any great extent. Where the battery is charged at reasonable intervals, the cells keep fairly warm. With my own car, which is kept in an unheated garage that reaches the full outside temperature in winter, I take this into consideration and allow for it. Whereas I have 120 amp-hr. available in summer, my limit is 100 amp-hr. in winter. There is not so much variation in commercial work; for instance, mine locomotives operate under fairly uniform temperature conditions and commercial electric trucks are worked hard and are out only about 8 hr. continuously in cold weather.

MR. SCHIFF:—I have noticed that temperature effect, particularly in tests of a large submarine type of battery. I have seen the capacity reduced about 30 per cent.

MR. BECK:—About 0.5 per cent per deg. at the normal rate represents the reduction in capacity. The number of ampere-hours is reduced if the temperature falls. In passenger-car service this must be taken into account. The general rule is to cut that down 25 per cent in freezing weather. The advantage of the red hand on the dial is that the driver does not need to know anything about the size of the battery or its capacity; he simply sets that red hand back. As an example of how effective this is, I cite one car that has never run out of power on the road in 8 years. That is one reason the battery is giving full capacity and has never been renewed or even had the electrolyte strengthened. This illustrates what protection against over discharge means and how the ampere-hour meter will provide such protection. The instrument is almost as important in connection with discharge as with charge. In commercial work it is felt in some large factories that the protection on discharge is more important than on charge. The Goodyear factory at Akron, Ohio, was bringing in trucks long distances for charge when the batteries were only one-quarter discharged. The company began leaving the trucks out twice as long after installing the meters, and this allowed them to work much more efficiently. This phase of the ampere-hour meter must not be overlooked; it does more than simply cut off the charge.

MR. ROTH:—If an ampere-hour meter could be made very cheaply, would it be used on the ordinary automobile also?

MR. BECK:—Yes, if it were reliable. Originally, an ampere-hour meter was used on the automobile, but it was of a cheap type and not altogether a success. However, some of those original batteries have had a wonderful length of life; some of them have lasted 7 years. We do not favor anything but the best ampere-hour meter of those available.

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

BRAKES AND SAFETY

IN a very comprehensive paper on passenger-car brakes, by J. Edward Schipper, published in THE JOURNAL for April, 1922, the general problems of brake design and the various types of brakes and brake mechanisms are discussed in a very interesting and thorough manner. This paper shows how much has been done in the line of developing brake mechanisms to meet the needs of the present-day passenger car with a reasonable amount of safety and freedom from trouble, and at a reasonable cost.

There are, however, some phases of the brake problem that seem to merit further consideration and the purpose of this article is to suggest some of them on which research of a more or less fundamental character is needed, as distinguished from the work of design and development.

The functions of a brake may be arbitrarily divided into two classes requiring somewhat different characteristics. These are

(1) Retardation of emergency stopping
(2) Absorbing power for long periods, as on grades

Much the greater amount of service of the brakes on the average passenger-car is of the first class, as in bringing the car to a stop or slowing down in traffic. The use of brakes on very short grades makes a similar demand to that made in ordinary retardation.

On some passenger cars used for touring in rough country, and on many trucks, however, the second class of service is of great importance. On long grades brakes, or the engine used as a brake, may be called on to absorb an amount of power nearly equal to the normal power output of the engine for considerable periods of time. Putting heat into a brake system by absorbing power in friction is something like dipping water into a leaky bucket. If the bucket is larger than the dipper, and we dip only occasionally, the water leaks out and does not overflow. But if we pour in a continuous stream, there is soon an overflow unless the water leaks out as fast as it flows in. This illustrates the two distinct properties of a brake system as regards its ability to take care of the heat which it receives.

First is its capacity for absorbing heat, corresponding to the capacity of the bucket. This capacity is about proportional to the total weight of the brake-drum and shoes. It does not matter how fast heat is generated if the total amount at any one brake-application is not more than the capacity of the brakes for absorbing it. The capacity is the amount of heat in British thermal units that can be absorbed without heating the drums to a dangerous temperature. The maximum amount of heat that can be developed in stopping a car at any speed is easily computed from the weight of the car and the speed. Not all of this goes into the brakes, but most of it may. However, the heat capacity of most brake systems is ample to care for this, and the real problem is that of how fast the brakes can be made to absorb the energy of the vehicle.

The requirements for the continuous absorption of power are entirely different. The heat capacity of the system is of little importance; of none, in fact, if brake application continues for many minutes. The important problem here is the heat leak, or the rate at which the brake system can dispose of the heat generated.

As the temperature of the brakes increases, the rate of heat leak increases, and the temperature will ultimately reach a point where the heat given out by radiation, convection, etc., equals the heat generated. The question then is, whether this temperature is destructive to the brakes when the power absorbed is what one could reasonably expect.

Most brakes will not meet this requirement in some parts of the Country, as Mr. Schipper points out in his paper. The area of the brake-lining and the holding power are ample for the purpose, but the provisions for disposing of heat are not. In fact, this feature seems to have been given little, if any, consideration in most brake systems.

Some of the problems that seem to need further investigation in the light of the foregoing discussion are as follows: In most cases brakes have obviously been designed like the rest of the car to meet average and not the most severe conditions. Brake failures have been responsible for many accidents and there is an insistent demand among traffic authorities in many quarters for some means of placing the responsibility for such failures. Official periodic tests of brakes have been advocated or adopted in some places. This demand has been so far justified that it is safe to assume some means will have to be found to meet it. To what extent are the designer, the production department, the service department and the user responsible for brake failures?

To what extent are accidents involving inadequate brake action dependent upon road conditions, and to what extent can the responsibility rest upon the highway designer and the driver of the car? Can traffic regulations be framed so as to place the responsibility where it belongs, and to keep the fact of this responsibility clearly before the mind? Certainly very much of the responsibility rests with the driver and fortunately he is easiest to reach. Correct answers to the foregoing questions would help in drafting regulations regarding brakes.

If there is to be a demand for brakes that will meet all usual conditions of service, there should be some accepted standard of service. Should brakes be designed so as to hold the car on any practicable grade and, if so, what should be considered a practicable grade? Is it a rational assumption that a car may be called on to coast down any grade at the same rate at which it would climb the grade? On this assumption it would be simple to fix a brake capacity in proportion to the power of the engine, the various power losses in the car being considered.

Brake-shoe pressures are rather a matter of design than of research, unless perchance there may be pressures beyond which it is not safe to go for some specific reason. But brake holding-power involves brake-shoe pressure and the coefficient of friction. The paper by S. Von Ammon in THE JOURNAL for March, 1922, describing the results of work done at the Bureau of Standards, raises one point of great importance in connection with the safety of brakes. While the normal coefficients of friction vary between wide limits, there are some conditions under which very abnormal values occur, namely when new brake-linings first become hot. In this case the coefficient may be reduced, with some lining materials, to perhaps one-fifth of the normal value. Should all brake linkages be designed to produce five times the pressure normally used, if this is possible, or should brake-linings be improved to overcome this tendency?

Much more should be known about brake-lining materials. However, this need is being met by an intensive research campaign on the part of many manufacturers of brake-

linings, which has followed the research undertaken at the Bureau of Standards.

Another question in the brake safety field is how much distance should be required to stop a car on a given road at any speed? And what is common practice in this respect? A few figures have been published showing the distance required. Some of these may be found in the Schipper paper, but the information is very meager indeed, particularly as regards different kinds and conditions of road. We believe that a systematic study of this problem for all classes of car and a wide variety of roads is of the utmost importance before any attempt is made to incorporate such figures in any form of traffic regulation that may be promulgated by any State or municipal authorities.

Other problems that may be considered in this connection are

(1) The effect of braking ability on the speed that can be maintained with safety in traffic

(2) The inherent advantages and disadvantages of four-wheel brakes

(3) The equalization of brake action on all wheels

(4) The possibilities of brake systems which will avoid skidding

Most of these topics are referred to in the following list of references.

BIBLIOGRAPHY

1. Passenger-Car Brakes. J. E. Schipper. THE JOURNAL, April, 1922, p. 273.
2. Developing a Method for Testing Brake-Linings. S. Von Ammon. THE JOURNAL, March, 1922, p. 153.
3. Conference on Brake-Lining Tests. Bureau of Standards. THE JOURNAL, July, 1921, p. 75.
4. Practice and Theory in Clutch Design. Herbert Chase. THE JOURNAL, July, 1921, p. 47.
5. Engineering Analysis of European Four-Wheel Brakes. W. F. Bradley and S. Gerster. *Automotive Industries*, June 16, 1921, p. 1267.
6. Report on Brake-Lining Conference Held at the Bureau of Standards, May 17, 1921. (Copy on file at the office of the Society.)
7. Braking Effects on Road Vehicles. F. A. S. Acres. *Automobile Engineer*, October, 1918, p. 298.
8. Retardation of the Automobile. John Younger. THE BULLETIN, January, 1917, p. 371.
9. Friction Brakes for Automobiles. R. Waring-Brown. *Automobile Engineer*, March, 1916, p. 75, and April, 1916, p. 106.
10. Jackshaft vs. Double Rear-Wheel Brakes. Arthur M. Laycock. THE BULLETIN, May, 1913, p. 216.
11. Method of Brake-Capacity Determination. S. I. Fekete. THE BULLETIN, June, 1912, p. 139.
12. Arrangement of Brakes. *Automobile Engineer*, March, 1911, p. 289.

MAY COUNCIL MEETING

THE meeting of the Council held in Indianapolis on May 8 was attended by President Bachman, Second Vice-President Young, Councilors Crane, Scott and Smith, and Past-President Beecroft.

Eighty-five applications for individual membership and 25 for student enrollment were approved. The following transfers in grade of membership were made: From Member to Service Member, Floyd B. Newell; Service Member to Member, Ernest W. Dean; Junior to Member, H. A. Schwartz, Dan R. Veazey, Walter R. Griswold; Junior to Associate, Bertram B. Webb; Associate to Member, C. W. Bassett, G. C. Brown, W. P. Hilton, Samuel Tour, Howard W. Draper, C. Eberhart, Jr., F. E. Whittelsey.

The financial statement as of March 31 showed a net balance of assets over liabilities of the Society of $124,110.89, this being $10,380.62 less than the corresponding figure on the same day of 1921. The income of the Society for the first 6 months of the current fiscal year amounted to $77,959.88. The operating expense during the same period was $92,-419.48. The expense accounts showed a net saving of $8,737.62 in comparison with the same activities for the same period of the last fiscal year.

The following appointments to the Standards Committee were made:

AERONAUTIC DIVISION
L. M. Woolson

AXLE AND WHEELS DIVISION
O. J. Rohde A. L. Putnam

BALL AND ROLLER BEARINGS DIVISION
J. T. R. Bell

CHAIN DIVISION
F. L. Morse

ELECTRIC VEHICLE DIVISION
Charles R. Skinner, Jr.

FRAMES DIVISION
E. A. DeWaters

NOMENCLATURE DIVISION
Leonard Ochtman, Jr. L. C. Voyles

NON-FERROUS METALS DIVISION
Samuel Tour

PARTS AND FITTINGS DIVISION
E. W. Weaver

PASSENGER-CAR BODY DIVISION
William Brewster

RADIATOR DIVISION
A. Ludlow Clayden

STORAGE BATTERY DIVISION
W. E. Goosling G. W. Vinal

TRANSMISSION DIVISION
C. H. Grill

The following additional subjects were assigned to the Standards Committee:

SUBJECT	DIVISION
Airplane Starting-Motor Mountings	Electrical Equipment
Battery Trays for Electric Trucks	Electric Vehicle
Cable Clips	Electrical Equipment
Carbureter Tests	Engine
Definitions	Springs
Engine Rotation	Motorboat
Gages and Gaging	Screw Threads
Magneto Flange Mountings	Electrical Equipment
Motorboat Tachometer Drive	Motorboat
Motor-Truck Cabs	Truck
Muffler Outlet-Pipe Couplings	Engine
Plain Washers	Parts and Fittings
Rubber Bushings	Electrical Equipment
Studs	Screw Threads
Stuffing-Boxes	Motorboat
Trimming Materials	Passenger-Car Body
Woodruff Keys	Parts and Fittings

J. M. Watson and C. N. Dawe were appointed to serve as representatives of the Society on the Committee on Gage Steel whose activities are conducted under the auspices of the Bureau of Standards.

Oil-Pumping

By GEORGE A. ROUND[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* DRAWINGS

OIL-PUMPING is defined and its results are mentioned. The influence of various operating conditions is brought out, particular reference being made to passenger-car service. The factors that control the rate of oil consumption are described in detail and some unusual conditions are reported. Various features of piston grooving and piston-ring design are mentioned and the effect of changes illustrated. The relative advantages of the splash and the force-feed systems as affecting the development of oil-pumping troubles are set forth and improvements suggested. A new device for reducing oil-pumping dilution troubles is described and illustrated.

OIL-PUMPING may be defined as the passing of oil into the combustion-chambers of an engine at a greater rate than it can be burned cleanly by the fuel charge. The results are spark-plug fouling and carbon deposits or in the absence of these difficulties the rate of consumption may be sufficient to cause complaints from the owners on the oil cost. The amount of oil that can be burned without trouble in any engine depends somewhat on the oil character but chiefly on the load factor and the correctness of the mixture. For example, an engine in tractor service will burn cleanly a volume of oil that in passenger-car service would cause excessive carbon deposits quickly. Again it is often the case that the engine that carbonizes in city service will burn clean in touring.

Because of the influence of the load factor it is possible to use in the more severe classes of service a type of lubricant that, while desirable from the standpoint of lubrication value and high economy, would cause undesirable carbon deposits in engines operating under more moderate conditions. In cars having a high acceleration rate the engine load factor under normal conditions has become very small. With the rich mixtures commonly used conditions are most unfavorable for burning cleanly any oil passing the pistons. This type of engine is also prone to knock readily with slight carbon deposits due to the high compressions usually employed. Consequently, it has been necessary to reduce the oil consumption in such engines to a point that is undesirably low from the dilution standpoint.

To assure good lubrication and to offset the effects of dilution it is desirable that the crankcase oil be renewed at reasonably frequent intervals. This can be accomplished in two ways; by (*a*) periodic draining of the entire supply or (*b*) the frequent addition of fresh oil to replace that used. In cars that show a very low oil-consumption rate the first method should apply, but in spite of repeated instructions to the owner to drain the old oil frequently, he finds it such a disagreeable task that it is not done as often as it should be, and contamination of the oil to an excessive degree is the result. It is a fact, however, that in many engines the rate of oil consumption increases to an undesirable extent after a comparatively short period of service, and it is in the control of this that we are chiefly interested.

FACTORS CONTROLLING OIL-PUMPING

The amount of oil passing an engine piston in a given time depends upon the following principal factors: (*a*) the amount of oil thrown to the cylinders, (*b*) number of piston strokes, (*c*) the efficiency of the means for piston drainage, (*d*) the ring fit, (*e*) the oil viscosity and character and (*f*) the vacuum in the cylinder. In his paper presented at the Annual Meeting last January,[2] Mr. Ricardo stated that he had been unable to find that the vacuum in the cylinder had any effect on oil-pumping. There is, however, some evidence to the contrary.

A few years ago an engineer working out a device to prevent oil-pumping sealed the crankcase of an engine against air leakage and maintained a vacuum in it equal to that in the intake-manifold. The tests conducted showed that the oil consumption could be cut in half when the vacuum was maintained. Smoking when accelerating after prolonged idling was eliminated, showing that the amount of oil passing the pistons was negligible. While that method of reducing consumption was impracticable, it showed that the vacuum in the cylinder was a factor affecting the amount of oil passing the rings, particularly in worn engines, and the idea has been applied successfully in another way that will be described later.

Experience seems to indicate that it is not possible to establish a definite rule for the variation in oil consumption with changes in the viscosity and the character of the oil used. In general the consumption decreases with an increase in the viscosity but in several tests we have encountered the reverse condition, under much the same conditions of design. In the engines in which this occurred the pistons were of cast-iron with no grooves or relief on the piston skirt. The ring next above the piston-pin was fitted somewhat loosely in its groove in the bottom of which was drilled a series of return holes. In one engine using force-feed lubrication and one employing splash the lower-viscosity oils invariably showed the best economy. The consumption figures for the first case, a small six-cylinder engine, were 1.37 lb. in 10 hr. for the lighter oil, and 2.1 lb. for the heavier under similar operating conditions. For the second engine, a small water-cooled single-cylinder lighting unit, the consumption of lighter oil was 0.5 lb. in 10 hr. and the heavier 2.6 lb. The consumption figures in both cases were corrected to allow for dilution. The viscosities at 210 deg. fahr. were 45 sec. Saybolt for the lighter oil, and 58 sec. for the heavier. Apparently the resistance of the lubricant in passing behind the ring to reach the return holes is the controlling factor, as with a different form of oil return the behavior of the oils is entirely normal. The character of the oil as affecting its evaporation rate, particularly at high temperatures as in tractor or heavy-duty truck service also has a bearing on the consumption. However, the more heat-resisting oils are not always desirable because from that very characteristic they may

[1] M.S.A.E.—Assistant chief of the engineering division of the automotive department, Vacuum Oil Co., New York City.

[2] See THE JOURNAL, May, 1922, p. 321.

not burn cleanly under moderate load conditions. In the majority of cases a compromise is desirable and that must be worked out largely on the basis of practical experience.

The Importance of Piston-Ring Fit

Proper piston-ring fit is one of the most important factors controlling oil consumption. When the rings fit correctly, the matters of clearance and provision for drainage become of minor importance. The chief points in regard to ring fit are the amount and uniformity of the tension of the ring and its clearance in the ring-groove. Experience has indicated that ring end-clearance is of minor importance in controlling oil consumption. If the rings are fitted with a minimum gap when new, the increase due to wear will have a negligible effect as compared with the other changes that take place.

Other factors being equal, the amount of oil consumed can be varied through a considerable range by changes in the ring pressure. This was clearly shown by some experiments on aircraft engines that were using too much oil. After fitting the bearings as closely as possible and cutting the pressures to a minimum, it was found that a 30-per cent reduction in the oil consumption could be effected by reducing the contact area of the rings about one-third as shown at the left of Fig. 1. It is interesting to note that this method was equally as effective as the other methods of reducing the area shown in the two central views of this illustration. This is contrary to the common opinion but it was checked several times in different engines.

The amount of pressure is, however, fairly definitely limited by the rapid wear that takes place when the ring tension becomes sufficient to cause all the oil to be scraped off. The pressure to cause this varies with the character of the lubricant and the nature of the cylinder and ring metals. A reasonable working limit, however, in terms of the pressure required to close the ring is approximately 2 lb. per in. of diameter for a ring of 1/4-in. width and the other sizes are in proportion. Uniformity of tension throughout the ring is of maximum importance and many cases of oil-pumping have been traced to the lack of this, due to either defective rings or their being distorted during assembly.

From recent experience, it is apparent that in some cases at least, not nearly enough attention is being given to ring inspection or to care in assembling them on the pistons. For instance, in one group of engines taken down to determine the cause of oil-pumping, a large number of rings were found bearing in spots only and of the new rings in stock, over 25 per cent proved defective. A little more care given to this detail would be of great benefit.

As to the relative merits of narrow and wide rings in controlling consumption, for equal wall-pressures there seems to be no difference. Because of their lighter weight the narrow rings do not wear the ring-grooves as rapidly, a decided advantage in aluminum pistons and one that gives them preference from that standpoint. In cast-iron pistons, a wide ring gives excellent results once it has worn to a fit.

The fit of the rings in their grooves is of prime importance. Our experience indicates that in engines where the amount of oil thrown to the pistons is constant throughout the engine life, as with splash systems, the oil consumption increases directly with the increase in the ring-groove clearance. Therefore, unless the lubricating system and the pistons are designed so that a minimum quantity of oil reaches the piston-rings throughout the normal life of the engine, oil-pumping will increase as the rings wear loose in their grooves.

With cast-iron pistons and rings of moderate width, the wear is not particularly rapid, although in motor-truck work it becomes noticeable in less than a year of service as a general rule. With aluminum pistons the wear is much more rapid and unless the oil supply is controlled effectively by other means, excessive consumption results. To avoid this increase in ring-groove clearance, rings have been made that, due to their design, stay tight in the grooves throughout their life. A typical ring of this kind is shown in Fig. 1 at the right. This ring we have found particularly effective in overcoming oil-pumping under a wide range of conditions.

The benefits of such rings are usually slight when compared with new and tightly fitted rings but show up to a marked degree in long service. One example of this was a 3½ x 5-in., four-cylinder engine that was fitted with rather heavy aluminum pistons having approximately 0.007-in. clearance. Using two plain rings above the piston-pin and one scraper ring, the oil consumption was about 60 miles per qt. of a medium-bodied oil. When the second ring was replaced with a ring of the type mentioned, the distance increased to approximately 150 miles per qt. and remained at that point until the pistons were discarded because of excessive slap after some 8000 miles of service. During this time the clearance of the other rings had increased to a marked degree. Numerous other similar cases are on record. While the scraper or skirt ring apparently has only a slight effect in most cases in reducing the oil consumption, it is of value in keeping the wear of the cylinder bore uniform.

Oil Grooving

The use of a properly designed drain groove with adequate return-holes is a great help in keeping oil consumption low, particularly after the rings have become somewhat loose in their grooves. While it has sometimes been the case with new engines that oil-return grooves have not shown much saving, in engines that have become somewhat worn they have proved helpful almost invariably.

Several different forms of return groove have been used. One of the earliest and most common types is shown in Fig. 2 at the left. For this the bottom edge of the lower ring-groove is beveled off slightly and a series of holes drilled from this bevel into the inside of the piston. Where the drain holes are of sufficient size and number and the space for oil collection provided by the bevel is of adequate size, this form of return is effective. It has, however, the decided disadvantage of reducing the area that supports the ring. Consequently, the ring-groove clearance tends to increase more rapidly than it otherwise would, thus defeating the purpose of the groove.

A more desirable form of groove is shown in the center of Fig. 2. With this, a full support of the ring is provided, together with a larger space for the accumulation of the excess oil. In some engines the most effective return has been by holes drilled in the bottom of the lower ring-groove as indicated at the right in Fig. 2. In these the best results have been secured when the ring was slightly loose in its groove and when using a light-bodied oil. Examples of this have already been given.

The size, number and location of the drain holes is an important factor. Holes smaller than 3/32-in. diameter are apparently ineffective unless a large number are used. With 3/32 or 1/8-in. holes, spaced approximately 1½ in. apart, satisfactory results are generally obtained.

With certain V-type engines, it has been found that the drain holes are effective only when placed as indicated in Fig. 3. When the holes are drilled on 360 deg. of the groove, the consumption increases. This is an unusual condition and one that has not yet been explained fully but is now under development.

The foregoing comments regarding grooving apply to the more conventional types of cast-iron and aluminum pistons. The latest forms of constant-clearance aluminum pistons are inherently self-draining and should perform satisfactorily provided the rings do not wear loose in their grooves too rapidly and, what is still more important, that the amount of oil thrown to the piston is not excessive.

Lubricating Systems

During the past few years we have seen a gradual trend toward the use of the force-feed lubricating system in which the connecting-rod dip is eliminated. The advent of the V-type engine made the use of this system necessary to assure a uniform distribution to the cylinders. Many have followed this lead in adopting pressure systems for other types, but the results as regards oil-pumping have not always been as happy as desired. The great disadvantage of the force-feed system from an oil-pumping standpoint is that the amount of oil thrown to the cylinders increases in proportion to the wear of the bearings and that unless special provision is made to offset it, the amount of oil supplied at light loads is far in excess of the requirements. In contrast to this the oil throw with splash systems remains constant throughout the engine life and may be proportioned so that, while the bearings receive ample lubrication, the cylinders are not over-lubricated beyond the ability of the rings to hold consumption to a reasonable figure, even when worn.

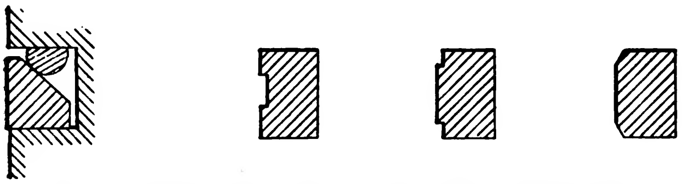


Fig. 1—Examples of Typical Piston-Ring Construction
The First Three Views Beginning at the Left Show How the Pressure of the Piston-Rings Against the Cylinder Wall Is Increased by Reducing the Contact Area, While the Illustration at the Extreme Right Shows a Ring That Is Designed to Remain Tight in the Groove

Perfection of bearing fits has done much to reduce the oil bleed in force-feed systems, but this is often nullified later by poor repair work and by excessive pressures. In connection with connecting-rod bearing leakage the ideal design uses no shims. Where these are employed either the lead-edged or plain brass shim is satisfactory only when fitted properly. If a bearing fails from lack of oil the lead edge will be destroyed and unless the bearing is refitted by a repairman familiar with the design that fact may be overlooked with resultant trouble. For truck and tractor service this shim seems less satisfactory.

In the conventional force-feed system employing a spring-controlled bypass, the capacity of the pump is far in excess of the bearing requirements. Consequently, this excess must be taken care of by the relief-valve, the adjustment of which determines the pressure in the system.

When the car or truck is delivered to the user, the pressure is set to give good results with tight bearings. Once he has the normal pressure as shown by the gage

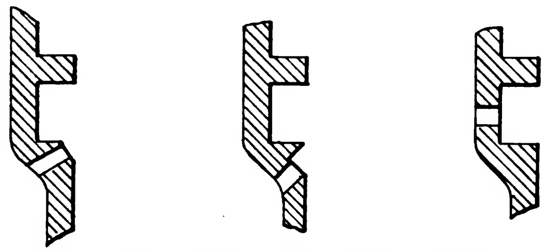


Fig. 2—Some Forms of Oil-Return Grooves

fixed in his mind, it is extremely difficult to convince either the user or the average repair-man that the drop in pressure that occurs as the bearing clearances increase, is not a danger signal. It is still more difficult to convince either of them that the proper remedy for the oil-pumping troubles that accompany the pressure drop can be overcome in part by a further reduction in the pressure, without endangering the engine.

In some cases, fixed adjustment relief valves are used and no pressure gages are employed. With such designs wide variations in the actual pressure maintained are certain to occur unless the relief valves are carefully calibrated, after assembly. In one case recently investigated, the opening pressure varied from 2 to 25 oz. in 10 valves taken at random from engines and stock. A test showed that the 2-oz. valves provided ample lubrication while with the higher tensions over-oiling was common. More rigid inspection of this important detail would eliminate a source of much trouble and expense to owners and dealers.

The effectiveness of a reduction in the oil pressure in worn engines is very marked, as the following cases show. In the first an eight-cylinder car, carrying normally about 12-lb. pressure under all conditions of speed and temperature, used about 1 qt. of oil for every 50 miles run and was carbonizing badly. Dropping the pressure to 5 lb. doubled the oil mileage and practically eliminated the carbon trouble.

The other case was a fleet of motor trucks that were giving excessive carbon trouble. The pressure in these engines ranged from 5 lb. when idling to 8 or 9 lb. at governed speed. When the bypass-valves were set to maintain an idling pressure of 1 lb. and a maximum of from 4 to 5 lb., the carbon trouble was eliminated, the average mileage per quart increased from 18.5 to 31.6, and no bearing trouble developed.

The experiences we have had with pressure systems indicate that a far smaller amount of oil is required to

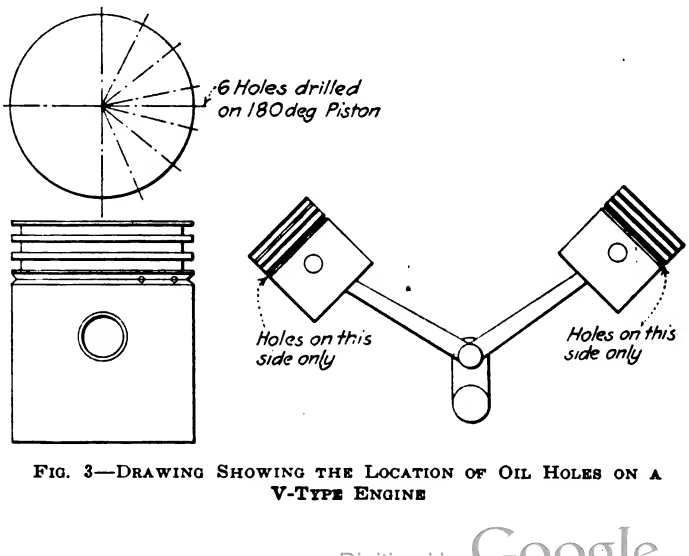


Fig. 3—Drawing Showing the Location of Oil Holes on a V-Type Engine

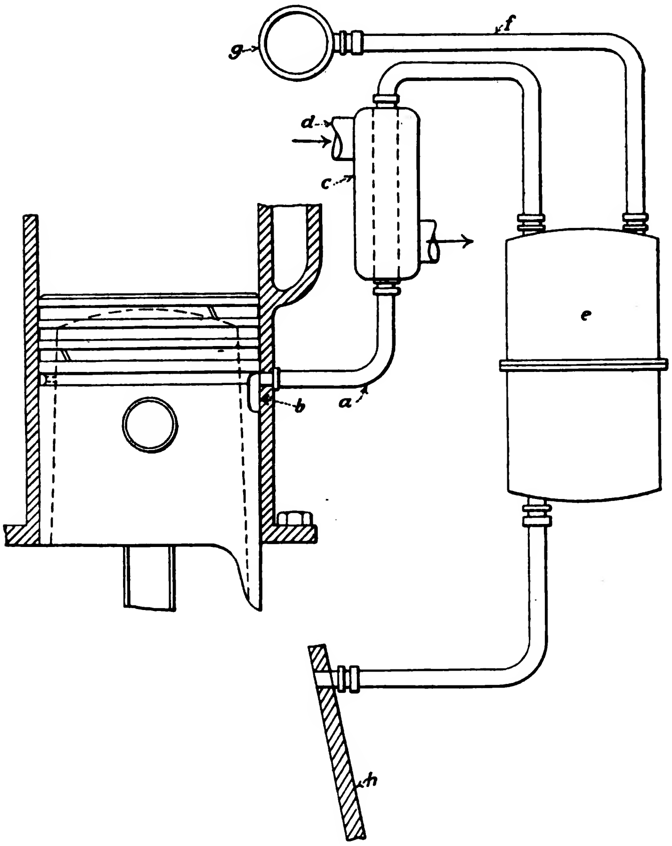


FIG. 4—DIAGRAMMATIC SKETCH OF A DEVICE DEVELOPED BY THE AUTHOR FOR OVERCOMING OIL-PUMPING AND DILUTION

lubricate a bearing adequately, and incidentally the cylinders and the pistons, than is generally supposed. Consequently, a marked reduction in the pressure and the volume of the oil supply will be of material advantage in reducing the oil consumption.

It may be contended that to meet the demands of extreme loads and speeds a large volume of oil is needed. There is some question in regard to this, as in many instances we have subjected engines to just such tests with a reduced oil supply, and always without damage. However, if it is felt that this over-supply is needed, some form of throttle or vacuum control of the oil pressure should be used to take care of the prevailing periods of light load.

Another method, which is more simple, is to provide an adjustable bleed in the pump delivery line that will allow the escape of sufficient oil to reduce the oil pressure at low speeds materially, while not preventing the development of high pressures at increased speeds.

A Novel Method of Controlling Oil-Pumping

Earlier in this paper it was mentioned that oil-pumping had been controlled by creating a vacuum in the crankcase to balance that in the intake. This idea has been applied in a very interesting way that not only tends to reduce oil-pumping to a marked degree, but also shows prospects of controlling our dilution and emulsion problems.

Referring to the diagram in Fig. 4, a connection *a* is made to the cylinder wall at a point that coincides with the lower limit of the travel of a groove *b*, located on the piston below the ring next above the piston-pin. A short vertical groove intersecting the circumferential groove and in line with the hole for the connection, is also cut in the piston. The connection *a* leads to a heater *c* that is connected to the exhaust manifold by the pipe *d* and thence to a separator *e*. From the upper part of this device a connection *f* is made to the intake-manifold *g*. The lower part of the separator is cut off from the upper by a valve and leads to the crankcase *h*. On the side of the piston opposite the connection a hole is drilled through the groove into the inside of the piston.

In the operation of the device the suction in the manifold is communicated to the groove on the piston, while the latter is near the bottom of its travel, and during approximately 90 deg. of crank rotation. The vacuum created draws into the heater any oil or oil and fuel mixture that collects in the groove and with it a small amount of air. In passing through the heater the mixture is heated by the exhaust to a temperature of about 375 deg. fahr. On reaching the separator any fuel or water present in the oil is evaporated and carried into the manifold. The remaining oil is passed into the bottom of the separator from which it flows back to the crankcase. To maintain on the other pistons the vacuum that would be destroyed when the upward travel of the piston uncovered the connection to the heater, a lip is cast or fastened on the lower edge of the piston. This keeps the connecting hole covered at all times.

The results of some tests of this device on a number of different cars and trucks of varying lengths of service and conditions, show an increase in mileage per gallon of oil ranging from 100 to 400 per cent. These tests were not short runs, but were carried on over periods of a year or more. As the effect of this device in connection with dilution is to be presented in another paper at a later date, it will only be mentioned in passing. However, the results seem to be very satisfactory and show that we have in prospect another method of solving the dilution problem.

Conclusions

(1) The lubrication requirements of engines, particularly in passenger cars, do not demand the volume of oil supplied by force-feed systems. Under normal operating conditions the volume of fuel burned is inadequate to consume completely the amount of oil passing the pistons

(2) Oil-return grooving is desirable in all cases and special rings may be required to control the excess oil supply caused by the wear in uncontrolled force-feed systems

(3) More rigid inspection of piston-rings and greater care in fitting them on the pistons will remove a common cause of oil-pumping. Oil-pressure relief valves should be carefully calibrated and set for lower pressures

(4) Some form of throttle or vacuum control is essential with force-feed systems, particularly when used on passenger-car engines

(5) Oil-pumping and dilution can be reduced by a new device that draws from the pistons any excess oil or liquid fuel present, the latter being driven off by heat and delivered to the intake-manifold while the oil is returned to the crankcase

Oil Consumption

By A. A. Bull[1]

Semi-Annual Meeting Paper *Illustrated with* Charts and Photographs

THE object of the paper is to consider some of the fundamental factors that affect oil consumption; it does not dwell upon the differences between lubricating systems. Beyond the fact that different oils apparently affect the oil consumption and that there is a definite relation between viscosity and oil consumption, the effect of the physical characteristics, or the quality of the oil, does not receive particular attention.

The methods of testing are described and the subject is divided into (*a*) the controlling influence of the pistons, rings and cylinders; (*b*) the controlling influence of the source from which the oil is delivered to the cylinder wall. The subject is treated under headings that include the piston-ring; the effects of oil-return holes, side-clearance and ring motion; thin rings; influence of piston fit; efficiency of the scraper-ring; ring and cylinder contact; carbonization and spark-plug fouling; oil-supply control; influence of oil viscosity; effects of dilution; external oil leaks and breather discharge, and influence of controlling lubrication in proportion to throttle opening.

THE subject of oil consumption, relating particularly to automotive engines, is one of importance. I realize the attention and effort that have been directed toward a solution of many of its problems by both the oil companies and the engine and vehicle builders.

From the owner's standpoint, the question of oil consumption in all its phases becomes of interest sooner or later. He is perhaps more interested in the troubles that he has experienced that result from excessive oil consumption or, as it is generally understood, oil-pumping. Over-oiling of this character, which occurs under average driving conditions and causes excessive carbon deposit and fouling of the spark-plugs, results in unsatisfactory operation of the engine. However, these symptoms are not necessarily characteristic, and engines that are not directly subjected to these troubles will use excessive quantities of oil; from an economic standpoint, this phase warrants consideration. The economic viewpoint of oil consumption is more important in truck and tractor engines, or those that are used in commercial service, where oil consumption affects operating costs. The object of this paper is to consider some of the fundamental factors that affect oil consumption and it will not dwell extensively on the difference in lubricating systems which, as will be self-evident, have an influence on oil consumption. Different oils apparently affect oil consumption and there is a definite relation between viscosity and oil consumption which can be attributed to several causes that will be discussed but, beyond this, the effect of physical characteristics or quality of the oil will not receive particular attention.

The extent of dilution has an important bearing on oil consumption in its effect in lowering the viscosity of the oil so that it cannot be controlled as readily. In passenger-car engines particularly the operator is likely to believe that his oil consumption is very small for the reason that the added diluent compensates for the actual oil consumed.

Apart from over-oiling as evidenced by excessive carbon, fouled spark-plugs and the like, what constitutes reasonable oil consumption? In commercial service, where operating costs must be kept to a minimum, perhaps the oil consumption should bear a definite relation to fuel consumption. The actual amount of oil required to lubricate the engine properly, particularly the pistons and cylinders, is surprisingly small and, because the oil pumped to the combustion-chamber is the chief source of oil consumption, attention necessarily is directed to controlling the extent to which oil reaches the combustion-chamber. The wide variation in oil consumption with different heavy-duty engines is well represented by the figures in Table 1. These figures have been collected from engines of different types, working, in most cases, under actual service conditions. The basis of comparison is the oil consumed per brake horsepower hour and, while this is not a direct indication of the relative con-

TABLE 1—OIL CONSUMPTION

Engine	Type	Speed, r.p.m.	Horsepower	Hours Operated	Oil Consumption, gal. Total	Per Hr.	Per B. Hp-Hr.
A	Tractor	....	....	97.00	......	0.2070	......
A	Tractor	....	....	379.57	......	0.1430	......
A	Tractor	....	....	426.59	......	0.1370	......
A	Tractor	....	....	2,997.00	......	0.1500	......
S	Tractor	....	20.0	37.00	9.7500	0.2630	0.01320
F	Tractor	....	18.0	34.00	3.7500	0.1100	0.00620
WB	Tractor	....	25.0	44.00	3.3800	0.0770	0.00370
C	Tractor	....	18.0	40.00	8.0000	0.2000	0.01110
C	Tractor	....	27.0	37.00	11.5000	0.3100	0.01150
AR	Tractor	....	30.0	35.00	15.5000	0.4420	0.01470
AR	Tractor	....	20.0	44.00	5.0000	0.1120	0.00560
RI	Tractor	....	16.0	33.00	4.3800	0.1330	0.00830
I	Tractor	....	20.0	30.00	8.0000	0.2670	0.01330
I	Tractor	....	16.0	32.00	4.7500	0.1490	0.00930
N_1	Truck[a]	....	37.0	5.00	0.4250	0.0850	0.00230
N_2	Truck[a]	....	30.0	4.00	0.0935	0.0234	0.00580
N_3	Truck[a]	....	27.5	4.00	......	......	......
A	Truck	1,500	33.0	1,000.00[b]	......	0.1200	0.00364
A	Truck	1,200	35.0	500.00[b]	......	0.0500	0.00143

[a] Maximum dilution, 1.5 to 2.0 per cent.
[b] Continuous.

[1] M.S.A.E.—Chief engineer, Northway Motor & Mfg. Co., Detroit.

sumption, it is based on the assumption that the engine speeds are nearly the same and that the horsepower output therefore indicates the size of the engine.

Oil consumption in passenger cars usually is computed on the basis of miles per gallon. It is possible to obtain figures as low as 50 and as high as 2000 miles per gal. As indicated previously, in ordinary service with low average speeds, the oil consumed may be negligible; in fact, it is possible that more fluid can be taken from the crankcase after service than was originally put in. On the other hand, engines or cars that will exhibit this characteristic will consume unreasonable quantities at continued speeds of 30 m.p.h. or over. An instance of this character which indicates a fairly general condition is indicated in Table 2.

TABLE 2—OIL CONSUMPTION

Car No.	1	2	1[c]	2[c]
Number of Cylinders	8	8	8	8
Average Speed, m.p.h.	15	15	40	40
Total Miles Run	600	500	50	50
Oil Consumption[d]	0	0.5	4-5.75	11
Dilution per Gallon, per cent	40	10	0	0
Oil Consumption, Excluding Diluent, miles per gal.	860	835	92	581

[c] Same cars on a speedway, at 40 m.p.h.
[d] The consumption for Cars Nos. 1 and 2 is given in gallons, in pounds and ounces for Car No. 3 and in ounces for Car No. 4.

Methods of Testing

In the study of oil consumption there are several methods in which comparative tests can be conducted. First, of course, tests under actual operating conditions are necessary to determine the average oil consumption and the general efficiency of the lubricating system. However, this method is not satisfactory in studying fundamentals, the chief difficulty being that it is not possible to have or control similar conditions of operation and equipment. Several methods were used in making observations in the laboratory.

(1) Obtaining the oil consumption under working conditions, properly controlling all the affecting factors
(2) Measuring the quantity of oil pumped through the exhaust of individual cylinders
(3) Studying the extent of the oil passing the pistons to the combustion-chamber with the cylinder-head removed

Method (3) gives very good results when checking fundamentals and is related closely to the results obtained by methods (1) and (2). In any case, in conducting oil-consumption tests it will be found that considerable variation in results is likely to be obtained unless great care is taken and until some fundamental has really been found. For this reason any small improvements or changes in oil economy that may be effected by the use of or changes in detail are not to be relied upon.

In studying the extent of oil-pumping by an observation of the amount collecting on top of the piston, the quantity of oil passed by is in excess of that which is used under working conditions, which assumption is drawn from the relative quantities of oil used. Every stroke of the piston functions the same, not being affected by the pressures existing in the cylinder during the cycle, the compression, expansion and exhaust pressures evidently having a beneficial influence and exercising more control than the effects of suction.

Before proceeding to a complete analysis, it is necessary to separate the subject into two classes (*a*) the controlling influence of the pistons, rings and cylinders; and (*b*) the controlling influence of the source from which the oil is delivered to the cylinder wall.

It generally is assumed that the piston-rings exercise the most important part in controlling the extent of oil-pumping. This is substantiated by the extraordinarily large number of different types of ring that claim in one way or another to control the oil consumption and eliminate the troubles usually associated with over-oiling. There are well established definite and fundamental principles that must be observed in the application of the rings to the piston, and the problem is one of maintaining the efficiency indefinitely. Unfortunately, the majority of replacement rings have no fundamental quality in themselves that affects or exercises control over the oil consumption and, in most instances where replacements are made, equally good results would be obtained by employing ordinary plain piston-rings.

An engine upon which some of the tests were conducted is illustrated in Fig. 1; its construction is self-evident. It has a full pressure-feed lubricating system, separate cylinder sleeves and the oil reservoir is divided into several compartments to filter the oil adequately.

The Piston-Ring

While the piston-ring primarily is used to retain compression in the cylinder, it has become necessary that the ring regulate or control the extent of the lubrication of the cylinder walls. Let us consider for a moment the action of the piston-ring in traveling the surface of the cylinder already coated with oil-film. During the expansion and suction strokes, when the ring is traveling down, it is presumed that it scrapes or pushes the excess oil adhering to the cylinder walls in front of it. In any case, this is exactly what the ring is required to do. The factors that apparently affect the efficiency of the ring in performing this duty are the thickness of the oil-film and the volume of oil, the unit pressure between the ring and cylinder, which determines its ability to break-down the oil-film, and the character of the leading edge of the ring.

The thickness of the oil-film depends upon the viscosity. In this connection it should be emphasized that the temperature of the oil in the main body of the oil-pan is not necessarily at the same temperature as the oil-film on the cylinder wall and, except under conditions where the cylinders are relatively cool, there is little variation in the viscosity on the cylinder wall. Quantitatively, of course, there will be more or less oil on the cylinder wall, depending upon the extent to which the oil is thrown from the connecting-rod and crankshaft bearing which,

Fig. 1—Sectional View Showing the Construction of the Engine upon Which the Tests Were Made

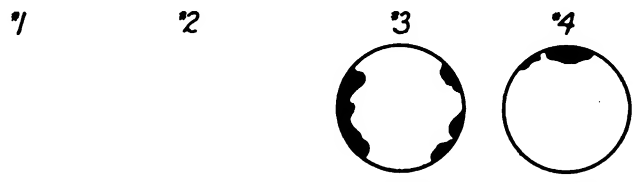


Fig. 2—Test Results Obtained at a Speed of 500 R.P.M., Oil and Water Temperatures of 109 and 127 Deg. Fahr. Respectively and an Oil Pressure of 12 Lb.

Cylinders Nos. 1 and 2 Were Equipped with a Single Piston-Ring and Had No Return Holes; the Other Two Cylinders Had Standard Three-Ring Equipment

as succeeding analysis shows, exercises a very decided influence.

The unit pressure between the ring and the cylinder wall has some effect on the efficiency of the ring in displacing the oil from the cylinder wall. With conventional cast-iron piston-rings, the wall pressure necessarily is limited by the stress that can be imposed on the ring material if it is to operate against the cylinder wall due to its inherent elasticity. The tension that can be obtained is adequate, although the increase in the unit pressure, obtained by a relief or a groove in the face of the ring or by the use of thin rings with a supplementary spring, will improve the scraping efficiency. As succeeding tests will indicate, however, this feature in itself is not sufficient to give the proper results. The character of the leading edge of the ring also has its effect and, unless it is relatively sharp, the ring will ride over the surface of the oil-film. For this reason a ring with a bevel is of benefit and, on the up-stroke, the ring will ride readily over the film. Along these lines, it is believed that the type of ring having an inherent twist, so that the unit pressure on the bottom edge is in excess of that on the top, may be beneficial.

Effect of Oil-Return Holes

Substantial force is required to displace the oil-film adjacent to the edge of the ring, and it is evident that a high pressure exists which, unless suitably relieved by the presence of oil-return holes, breaks-down the seal be-

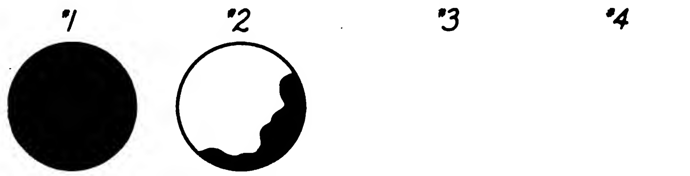


Fig. 3—Test Results Obtained with the Same Equipment as in Fig. 2 at a Speed of 1000 R.P.M.

The Difference in the Oil Deposits in Cylinders Nos. 2 and 3 as Compared with Fig. 2 Should Be Noticed

tween the face of the ring and cylinder. Reference to Figs. 2, 3 and 4 clearly illustrates the effect of oil-return holes. Fig. 5 shows the same ring equipment operating at the normal oil temperature of 142 deg. fahr., but with oil-return groove and holes immediately below the ring. The improvement is evident. The ring used in the preceding test had a good fit in the groove. However, it is recognized that sidewise clearance increases with use.

The diagrams and photographs that refer to the test results are presented as representative selections of a considerable number of tests. Both photographs and scale diagrams are shown in some instances. In some cases, scale diagrams alone are shown because they offer a better comparison. The variation in ring construction is made on cylinders Nos. 1 and 2, the same rings being used in each case and being placed in the same circumferential position. Cylinders Nos. 3 and 4 have standard three-ring equipment, except where otherwise noted. Cylinders Nos. 1 and 3 have similar oil distribution from the crankshaft, while cylinders Nos. 2 and 4 differ as will be explained later. The relative effect of change in ring construction on the amount of oil-pumping with the different oil distribution can be compared in cylinders Nos. 1 and 2.

In Fig. 2 cylinders Nos. 1 and 2 were equipped with one ring and had no oil-return holes. Cylinders Nos. 3 and 4 were provided with standard three-ring equipment. The oil pressure was 12 lb. per sq. in.; the oil temperature, 109 deg. fahr.; the water temperature, 127 deg.

Fig. 4—Photographs of the Oil Deposits Shown (Above) in Fig. 2 and (Below) in Fig. 3

fahr.; the speed, 500 r.p.m.; and the duration of the test, 3 min.

In Fig. 3 the same conditions prevailed as in Fig. 2, except that the speed was 1000 r.p.m. and the duration of the test was 1 min. The difference in the increase in the oil deposit on cylinders Nos. 2 and 3 should be noted.

In the upper portion of Fig. 5 the oil pressure was 12 lb. per sq. in.; the oil temperature, 156 deg. fahr.; the

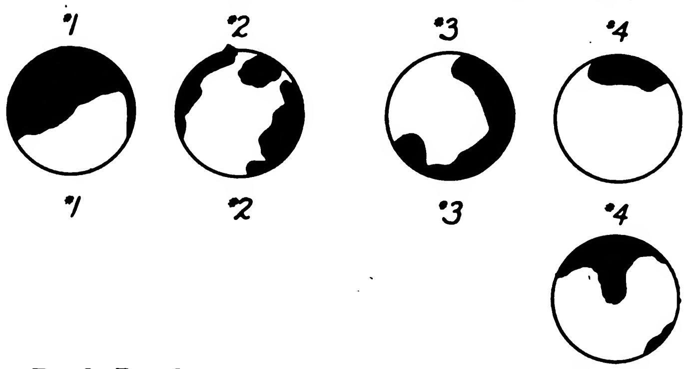


Fig. 5—Test Results Obtained (Above) at 500 R.P.M. and (Below) at 1000 R.P.M.

Cylinder No. 1 Had One Ring with Oil Holes Immediately below the Ring

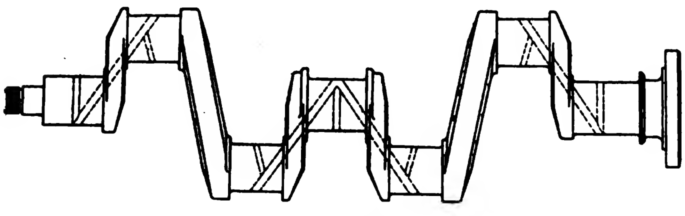


FIG. 6—CRANKSHAFT IN WHICH OIL-HOLE LOCATION COULD BE CHANGED FOR THE EXPERIMENTS

speed, 500 r.p.m.; and the duration of the test, 3 min. Cylinder No. 1 had one ring, with oil-return holes immediately below the ring. In the lower portion of Fig. 5 the same conditions prevailed as in the upper portion, except that the speed was 1000 r.p.m. and the duration of the test was 1 min.

Fig. 6 shows the crankshaft, in which the oil-hole location could be changed during the experiments.

Fig. 7 illustrates part of the equipment used for measuring the quantity of oil pumped through the exhaust.

EFFECTS OF SIDE-CLEARANCE AND RING MOTION

Digressing for a moment, let us consider the effects of side-clearance on the ring. During the down-stroke of the piston, the ring is contacting with the upper face of the groove leaving the clearance at the lower edge; on the up-stroke, the condition is reversed. Having recognized that oil pressure is built up on the under side of the ring, it follows that, if the ring is not seating on the groove, the oil will pass through to the rear of the ring.

The three factors which control the movement of the ring relative to the piston are the

(1) Inertia of the ring itself or its resistance to acceleration
(2) Friction of the ring against the cylinder wall
(3) Effects of pressure within the combustion chamber

Fig. 8 shows the inertia and friction forces operating on the ring at 1000 r.p.m., indicating that the position of the ring does not change in respect to the groove. At higher speeds, however, the position changes before the end of the stroke.

The effect of side-clearance on oil-pumping is illustrated in the two portions of Fig. 9. The oil is pumped up very rapidly, with or without an oil-return hole below the ring. At 500 r.p.m. piston No. 1 is covered completely in 1 min., but it becomes full in 0.3 min. at a speed of 1000 r.p.m. In the upper portion of Fig. 9 cylinders Nos. 1 and 2 each have one ring with a 0.005-in. side-clearance and cylinders Nos. 3 and 4 are provided with standard three-ring equipment. At a speed of 500 r.p.m. and a duration of test of 3 min., cylinder No. 1 fills up in 1 min. In the lower portion of Fig. 9 the conditions are the same as in the upper portion, except that the speed is 1000 r.p.m. and the duration of test 1 min. Cylinder No. 1 fills up in 0.3 min. Fig. 9 should be compared with Fig. 5.

In this connection consideration should be given to the extent of the side-clearance that occurs in the ring-groove. With cast-iron pistons and rings the initial fit can be established fairly well and, under operating conditions, the expansion of the ring is practically the same as that of the groove; consequently, no additional clearance occurs until the ring or groove becomes warm. It is not possible to determine when increased clearance will occur, as this depends on the conditions under which the engine is operating. With a three-ring piston the actual clearance will vary from the top down in about the following relation: upper, 0.010 in.; second, 0.006 in.; and third, 0.003 in.

The extent of side-clearance unquestionably is the factor that is responsible for any difference between cast-iron and aluminum pistons. Regardless of the accuracy of the fit of the ring in the groove, the difference in expansion between the ring-groove and the ring on an aluminum piston produces initial clearance in excess of that required to effect the proper seal and increase in the rate of wear between the ring and groove because of the initial reciprocation. The use of oil-return holes in the ring-groove at the back of the ring is very beneficial when the ring has side-clearance so that the oil has access to the space back of the ring.

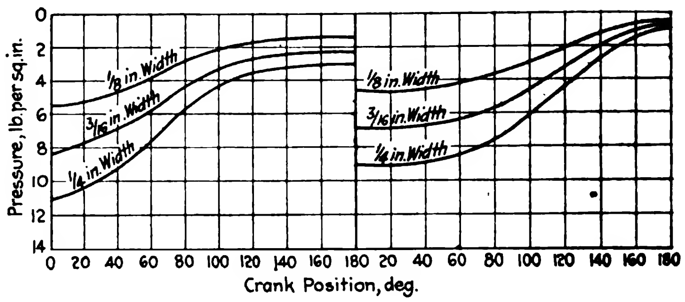


FIG. 8—DIAGRAM SHOWING THE UNIT PRESSURE ON THE RING-GROOVE PRODUCED BY FRICTION AND INERTIA FORCES OF RINGS OF DIFFERENT WIDTHS AT 1000 R.P.M.

FIG. 7—PART OF THE EQUIPMENT FOR MEASURING THE QUANTITY OF OIL PUMPED THROUGH THE EXHAUST

The two halves of Fig. 10 indicate the benefits of these oil-return holes. In the upper view the engine is operated at 500 r.p.m. and at 1000 r.p.m. in the lower, the equipment being the same. It is obvious that, with holes so located, particularly when used in a ring-groove above the piston-pin, the ring is useless for retaining the compression. Cylinders Nos. 1 and 2 each have one ring with 0.005-in. side-clearance, and oil-return holes in the ring-groove. Cylinder No. 3 has rings 1/8 in. wide and no relief-holes. The duration of the test was 3 min. for the upper view and 1 min. for the lower. Fig. 10 should be compared with Fig. 9.

THIN RINGS

The influence of ring thickness on side-clearance has received considerable attention, particularly for use with

aluminum pistons. Reduction in ring thickness unquestionably reduces the relative clearance. The weight of the ring itself is reduced, consequently decreasing the inertia effects of the ring. The relative forces with rings of different thicknesses are represented in Fig. 8. Fundamentally, however, they cannot solve the difficulty. A multiplicity of thin rings in a narrow groove would provide a good solution. They must be made of steel rather than cast-iron, and they must be hard so that they will not lap the bore and cause excessive wear. An effective unit-pressure of the ring against the wall could be well maintained and, likewise, the inertia effects of the portions of the ring would be dampened out by the oil-film between the several rings. Circumferential sealing also would be improved. Piston No. 3 in Fig. 10 is equipped with four 1/8-in. rings above the piston-pin without any relief-holes, from which it would seem that no benefits are obtained.

Combining all the essential requirements of a ring, it seems that a ring of two-piece construction capable of sidewise expansion is desirable. It is important, however, that sufficient wall pressure be provided; otherwise the benefits of the side-seal are lost with the inability of the ring to displace the oil from the cylinder wall properly.

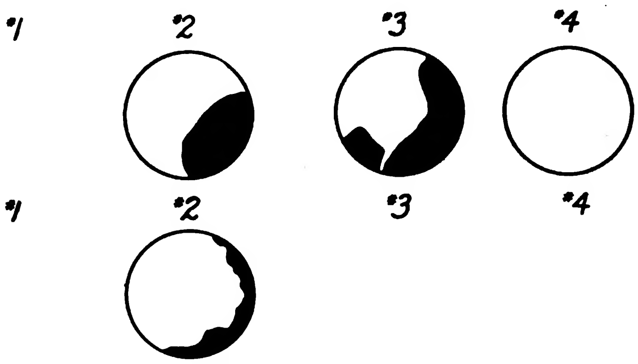


FIG. 9—TEST RESULTS OBTAINED (ABOVE) AT 500 R.P.M. AND (BELOW) AT 1000 R.P.M.

Cylinders Nos. 1 and 2 Had One Ring with a Side Clearance of 0.005 In., While the Other Two Had Standard Three-Ring Equipment. The Lower Speed Cylinder No. 1 Filled in 1 Min. and in 0.3 Min. at the Higher Speed. These Diagrams Should Be Compared with Those in Fig. 5

The clearance of the piston in the cylinder unquestionably has some effect on the functioning of the ring; however, this is not because an increased clearance between the piston and cylinder permits a larger quantity of oil to accumulate. From a fundamental standpoint the oil-film is not likely to be any thicker with a loose piston than a tight one. The oil pressure built up ahead of the ring, however, is increased with the closer fit because the oil-film is confined more closely.

Piston fit in the cylinder has an appreciable effect on the wear of the rings; on both the outside, which contacts with the cylinder wall, and the sides contacting with the ring-groove. It is evident that the piston will rock in the cylinder to the extent of the clearance, and that it tends to form a convex surface on the outside of the ring, completely destroying its oil-scraping efficiency. The continual sliding back-and-forth of the ring upon the seat wears the ring-groove very rapidly, and it is believed it is more responsible for wear than the actual pressure exerted by the ring on the groove because of its reciprocation.

On the basis that the ordinary ring is likely to carry up as much oil as it will scrape down, the use of the fourth ring below the piston-pin is of little advantage, except that it maintains its fit and condition very much better than the others and therefore has merit. Fundamentally, the use of a fourth ring placed at the lower end of the piston increases the amount of oil to be handled. It follows that the scraper-ring itself travels over a filmed surface equivalent to the stroke of the piston, while the upper rings also travel over a surface of similar length, the accumulated travel being greater and the oil consequently being relayed from one ring to the other. It is interesting to observe that, without any ring on the piston, absolutely no oil is passed up, the piston sliding over the lubricating film without disturbing it.

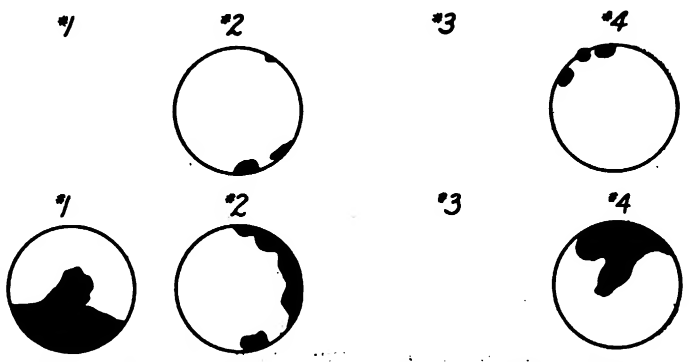


FIG. 10—HOW THE PRESENCE OF OIL-RETURN HOLES AFFECTS THE FORMATION OF OIL DEPOSITS

Cylinders Nos. 1 and 2 Were Equipped with One Ring Having a Side Clearance of 0.005 In. and Had Oil-Return Holes in the Ring-Groove, While Cylinder No. 3 Was Fitted with Rings 1/8 In. Wide and No Relief Holes. The Upper Drawing Shows the Results Obtained at 500 R.P.M. and the Lower One Those Obtained at 1000 R.P.M. These Results Should Be Compared with Those of Fig. 9

RING AND CYLINDER CONTACT EFFECTS

Plain rings change their position circumferentially in the cylinder and, if the cylinders are out-of-round, which is usual, due to unequal expansion and the like, considerable oil will be passed by the rings. It was evident in all the tests that have been conducted that the location of the ring circumferentially is very important and, in duplicating results, it is necessary to pin the rings so that they cannot rotate. To illustrate the extent to

FIG. 11—APPARATUS USED FOR THE DETERMINATION OF PISTON-RING PRESSURE

With Multiple-Piece Rings, the Pressures Were Taken with the Ring Installed in the Groove

FIG. 12—SOME OF THE VARIOUS TYPES OF RING WITH WHICH THE EXPERIMENTS WERE CONDUCTED

which contact between the ring and cylinder affects consumption, the following comparison is submitted.

As a result of using separate cylinder sleeves, it was possible to obtain an ideal comparison. The pistons and rings remained undisturbed and new cylinder sleeves were used, the engine having seen considerable service. With old rings and cylinders, the oil consumption was 400 miles per gal. and with the same rings and pistons, but with new cylinders, the oil consumption was 150 miles per gal.

Summarizing the fundamental factors of the piston ring, we conclude that

(1) Drain-holes are absolutely essential
(2) An angular-faced piston-ring is beneficial
(3) The proper mechanical fit between the ring and the groove is essential
(4) Oil relief-holes in the rear groove are beneficial when side-clearance occurs
(5) The slot in the rear is unimportant
(6) The number of rings is unimportant

Fig. 11 shows the apparatus used for the determination of piston-ring pressure. With multiple-piece rings, the pressures were taken while the ring was installed in the groove.

Fig. 12 shows some of the various types of ring with which the experiments were conducted, and Fig. 13 illustrates several types of piston that were installed during the tests. Pistons having one ring-groove only were employed in obtaining the data on ring characteristics.

Table 3 gives piston-ring pressures taken in the groove and taken free. Table 4 shows the relative unit wall-pressure with change in contact area and face width.

Passing from a consideration of the mechanical aspects of rings and pistons in the controlling of oil passing to the combustion-chamber, mention should perhaps be made of some of the factors affecting carbonization and the

TABLE 3—PISTON RING PRESSURES

Ring Diameter, Outside, 3½ in.; Ring Width, 3/16 in.

Kind of Ring	Weight in Pounds, at Deflection of 0.001 in.	0.002 in.	0.003 in.
Weight Taken on Ring Not Installed in Groove			
Concentric, Hammered	4.96	6.10	6.650
Two-Piece, Outer	1.28	1.52	1.850
Two-Piece, Inner	.....	0.64	0.775
Three-Piece, Spring Type, Outer	0.00	0.00	0.000
Three-Piece, Spring Type, Inner	0.00	0.52	0.640
Weight Taken with Rings Installed in Groove			
Hammered	5.20	6.40	7.000
Two-Piece	3.00	3.65	4.400
Three-Piece, Spring Type	6.40	10.40	13.200
Hammered, Spring Type	15.90	24.52	33.000

TABLE 4—RELATIVE WALL PRESSURE OF RING OF 3½-IN. OUTSIDE DIAMETER

Outside Diameter of Ring, 3½ in.			Deflection	0.001 in.	0.001 in.
Ring Width, In.	Normal Ring Tension, Lb.	Developed Contact Area, Sq. In.	Wall Pressure, Lb. per Sq. In. Normal	Tight	Loose
3/16	4.5	0.665	6.75	8.25	5.25
1/8	4.5	0.404	11.20	13.60	8.65
3/32	4.5	0.341	13.20	16.20	10.20

fouling of spark-plugs after the oil has reached the combustion-chamber. First, of course, is the nature of the lubricant. It usually is considered that the heavier oil produces more carbon deposit, although this is not always true. The extent of the free carbon in the lubricant has little effect upon combustion-chamber deposits. In this respect the benefits of proper heat conductivity on the piston-head, to prevent excessive carbon deposit on the inside, should be observed. The location of the spark-plug is of great importance, as in many cases, of course, frequent fouling of the spark-plugs has been a result of improper location, the least evidence of over-oiling immediately affecting its operation.

A typical condition of cylinder-head carbon-deposit is shown in Fig. 14. The maximum deposits are on the side of the cylinder upon which most of the oil is thrown from the crank, the spark-plugs being sufficiently removed from this zone to prevent their becoming carbonized.

CONTROL OF THE OIL SUPPLY

Control of the oil supply, particularly that from the bearings to the cylinders, unquestionably has more influence on the oil consumption than the mechanical condition of the pistons and the rings. Stated briefly, it is very evident that, under the best conditions, the rings and the pistons can only exercise a very definite control over the amount pumped to the combustion-chamber.

In the discussion of the mechanical aspect of the pistons and the rings, it is concluded that there are definite fundamental conditions that must exist to control the oil

FIG. 13—SEVERAL TYPES OF PISTON INSTALLED DURING THE TESTS
Pistons Having One Ring-Groove Only Were Employed in Obtaining the Data on Ring Characteristics

FIG. 14—A TYPICAL CYLINDER-HEAD SHOWING THE CARBON DEPOSIT IN A TRACTOR ENGINE

passing to the combustion-chamber to the best extent, and the problem of the piston-rings and the pistons is to maintain these fundamental conditions. This same argument holds for the control from the source of supply. It is probable that, with the very close fits of bearings, the extent of oil discharge to the cylinders will be of such magnitude that the rings can control it properly. As wear of the bearings occurs, the discharge is increased greatly and this is true particularly where an oil-regulating mechanism is provided that will maintain the oil pressure even though the bearings become loose.

It will be further evident from the analysis yet to be made that, in most instances, the effect of higher speed is to increase the quantitative discharge from the bearings and it will be shown that, while ordinarily higher speed will increase the oil consumption considerably, it is believed that this is not due to any change in functioning of the piston-rings in keeping the oil from passing into the combustion-chamber. In other words, the rings will be almost equally efficient within the ranges of piston speed under average conditions, if they are fitted properly.

Trucks and tractor engines that operate a large percentage of the time at governed speeds are affected greatly in their oil consumption by the bearing condition. It is also true of passenger-car engines that a car will show a reasonable economy when operated at ordinary driving speeds and, while this economy may be more or less superficial as a result of the dilution that takes place, the same car running at higher speeds, where dilution does not become a factor, will consume unreasonable quantities.

The consideration of the oil discharge from the crankcase is, naturally, confined largely to pressure-feed systems. With splash feed for the connecting-rods, the amount thrown onto the cylinder wall depends, of course, on the dip. It is not controlled as easily except through the use of baffle-plate. In most instances pressure-feed crankshafts are provided with an oil-hole in the crankpin radially outward, in which position the extent of the oil discharge is affected greatly by bearing clearances.

Let us refer for a moment to two diagrams in Fig. 15 which indicate the pressure distribution on the crankpin bearing throughout the cycle at a speed of 500 r.p.m. It is evident that, throughout the greater portion of the cycle, the pressure on the pin is radially outward in the region of the inside of the crankpin, thus locating the clearance in the bearing on the outside. As it approaches the center on the compression stroke, and likewise on the expansion stroke, the pressure is reversed.

Fig. 16 gives the pressure distribution at 1500 r.p.m. under full load. The increase in the magnitude of the inertia and centrifugal forces, as the speed increases, is such that the resultant pressure on the pin is radially outward except for an angular travel of 100 deg. during the expansion stroke. It is evident from these figures that, at all speeds and particularly as the speed increases, the pressure on the pin is concentrated chiefly on the inside, thus locating all of the bearing clearance on the outside of the pin. When running under no load, this condition is emphasized. It is clear that, with the oil-hole placed on the outside of the crankpin, the clearance of the bearing will be located in the vicinity of the hole most of the time, thus permitting a free opening through which the oil can be discharged. The oil discharged from the crankpin has a direction tangentially forward from the point of discharge; so, it will be evident when approaching the upper center that the oil discharged from the crankpin is directly in line with the cylinder. Bearing wear and increased clearance will therefore have a marked effect on the quantity of oil thrown from the bearing and, from the figures that follow, it points very conclusively to the influence bearing clearance has on oil-pumping and oil consumption.

Fig. 17 is a reproduction of similar pressure-diagrams

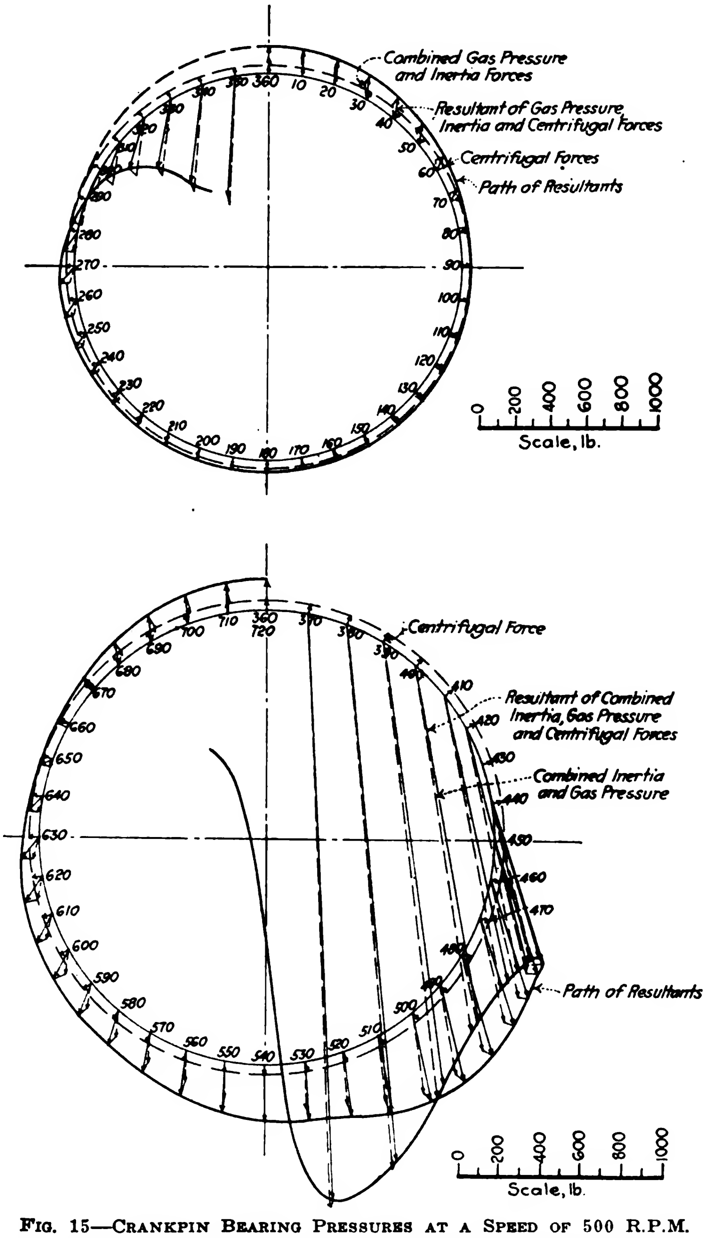


FIG. 15—CRANKPIN BEARING PRESSURES AT A SPEED OF 500 R.P.M. The Upper Diagram Is for the Intake and Compression Strokes; the Lower for the Expansion and Exhaust Strokes

TABLE 5—OIL CONSUMPTION

Car No.	Type of Rings	Oil-Hole Location	Total Miles Run	Speed, m.p.h.	Oil Consumption, Miles per Gal. Total	Distributing Hole Outside	Distributing Hole Inside
Series No. 1							
Experimental	Standard, Old	0	50	40	76.00	......	......
Experimental	New	0	50	40	143.00	......	......
Experimental	New, ⅛ In.	0	50	40	64.00	......	......
Experimental	Special	0	50	40	221.34	......	......
Series No. 2							
G	Standard, Old	0	50	40	139.00	......	......
G, Trial No. 1	Special	0	50	40	300.00	......	......
G, Trial No. 2	Special	0	50	40	240.00	......	......
G	Standard, Old	1	50	40	755.00	......	......
Series No. 3[e]							
58,301	....	..	50	40	......	156	382
O. B.	....	..	50	40	......	151	388
60,887	....	..	50	40	......	156	692
65,629	....	..	50	40	......	294	512

[e] In this series only the changes in the oil distribution were considered, losses from other sources being neglected.

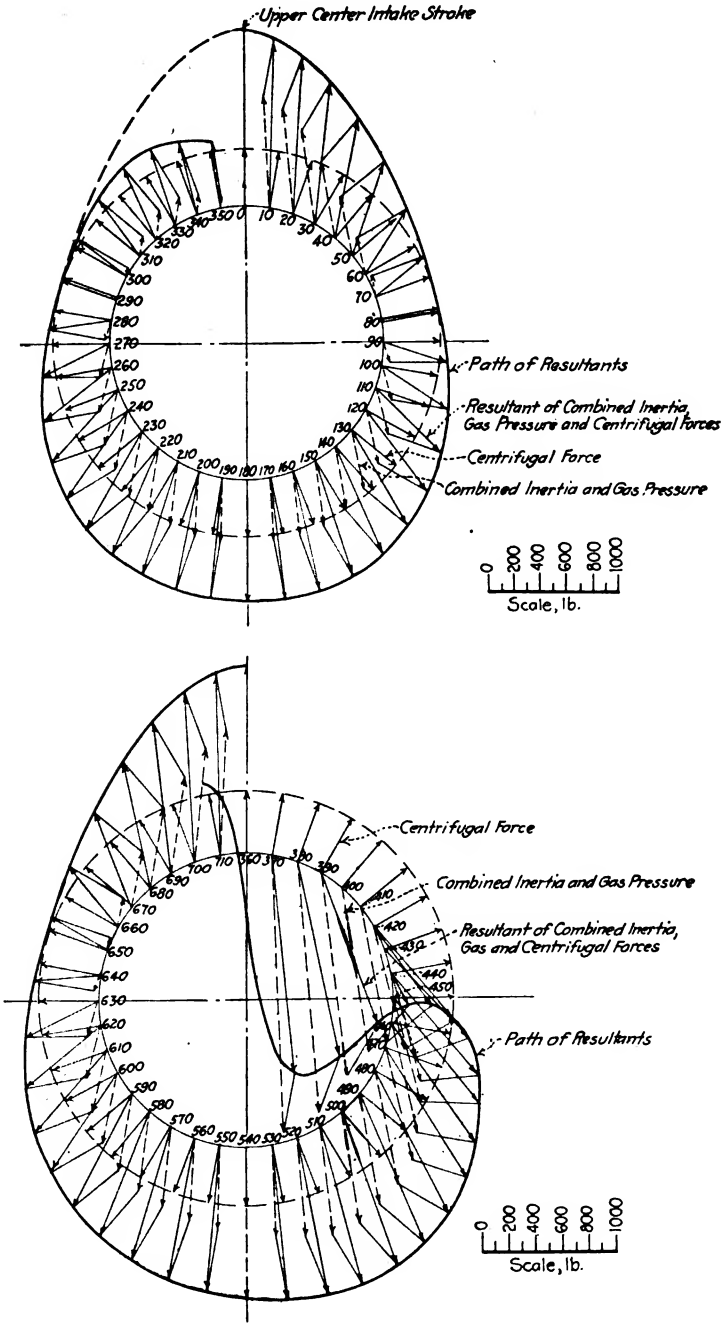


Fig. 16—Crankpin Bearing Pressures at a Speed of 1500 R.P.M. The Upper Diagram Is for the Intake and Compression Strokes; the Lower for the Expansion and Exhaust Strokes

of eight-cylinder V-type engines, for which the same arguments hold true. To control the extent of oil discharged to the crankpin, it is clear that the oil-hole should be located to maintain a continuous seal regardless of the bearing clearance and the speed; therefore, it should be in the zone of continued pressure, preferably radially inward on the inside of the crankpin.

To appreciate the influence of oil-hole location on the extent of oil-pumping and oil consumption, compare cylinders Nos. 3 and 4 in the preceding figures, that have standard ring equipment. In all the preceding tests the bearing clearance was increased purposely to approximate service conditions. The comparative quantity of oil as measured from the exhaust discharge or as clearly pictured in the preceding diagrams between cylinders Nos. 2 and 4 and Nos. 1 and 3 is very marked. Fig. 9 shows this condition particularly well. With the same piston-ring equipment in cylinders Nos. 1 and 2, cylinder No. 1 is considerably more affected by a change in the rings. The influence of speed can be observed also. Piston No. 1 becomes noticeably worse, while piston No. 2 is not affected appreciably.

The tests reported in Table 5 are submitted in further support of the controlling influence of crankpin discharge, and the effects of special piston-ring equipment can be observed also. In series No. 3 the oil consumption obtained at 40 m.p.h. with standard ring equipment and the outside oil-hole on the crankpin is given, and also the oil consumption in miles per gallon obtained with the oil-hole on the inside, all other conditions remaining the same. Series No. 3 should be compared with Series No. 1, which shows differences in ring equipment. The use of special ring equipment effected an improvement in some cases but, upon succeeding tests, the oil consumption would increase gradually.

It is interesting to note that increasing the load has the effect of establishing the bearing clearance in the vicinity of the oil-hole when located on the inside through a part of the expansion stroke and, consequently, it exercises a very favorable control on the amount of oil supplied in proportion to the load. From the standpoint of effective lubrication of the pin some arguments can be advanced but, from a consideration of Fig. 18, it would appear that better oil-film distribution is obtained with the inside location of the oil-hole, the influence of centrifugal force tending to distribute the film around the bearing, while with the outside oil-hole the oil is immediately thrown from the bearing. Actual experience has proved that bearing failures at high speed are less pronounced with the inner location of the hole, and that dirt will not score the bearing so readily. Efforts to time-

the oil supply to the crankshaft through the main bearings properly, so that the discharge from the pin would not occur when the shaft was passing the cylinder, proved unsuccessful, because the quantity of oil in the channels of the shaft disturbed the control. The effect of main-bearing discharge should be considered also. It

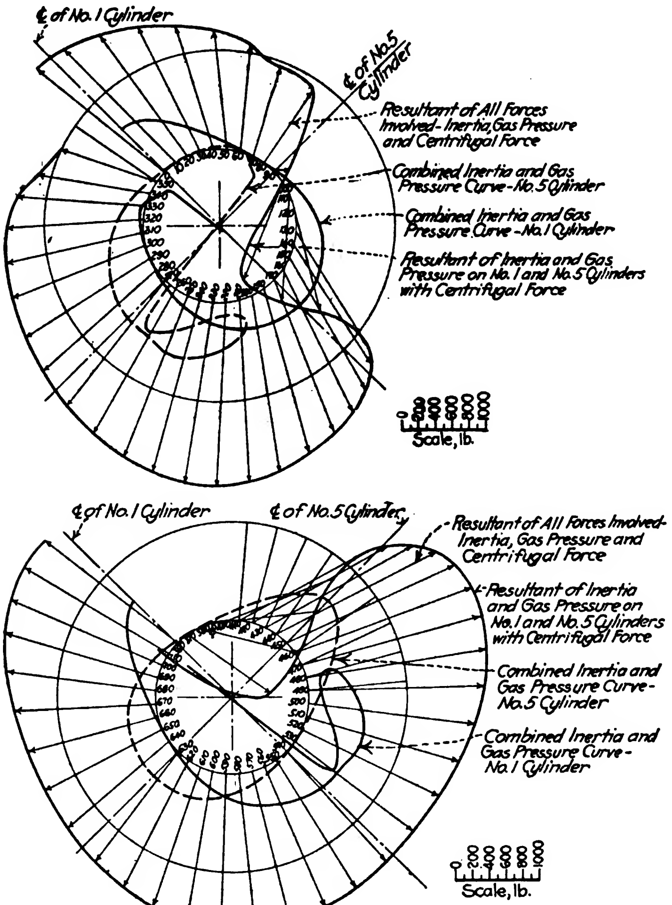


FIG. 17—CRANKPIN BEARING PRESSURES IN AN EIGHT-CYLINDER 90-DEG. ENGINE AT 2000 R.P.M.
The Upper Diagram Is for the Intake and Compression Strokes; the Lower for the Expansion and Exhaust Strokes

is of advantage to provide a thrower flange adjacent to the rear bearings so that the oil cannot reach the crankpin hole and, consequently, be discharged directly into the cylinder.

An interesting test was conducted to determine the relation between pressure feed and splash feed. An engine was converted to use a splash-feed system, retaining the same piston equipment. It was observed that almost any result could be obtained with the splash feed and, if adequate lubrication were provided for the pin, an excessive quantity was thrown into the cylinders unless a baffle-plate was used. The troughs into which the rods dipped were made so that they could be raised and lowered as desired.

INFLUENCE OF OIL VISCOSITY AND EFFECTS OF DILUTION

A reduction in oil viscosity as a result of an increase in oil temperature, dilution or the use of light oils, will increase proportionately the oil consumption by reason of the additional discharge from the crankpin under the same pressure, unless the oil-hole is located in the zone of pressure so that it exercises a definite control. With an engine so equipped, practically no difference is ob-

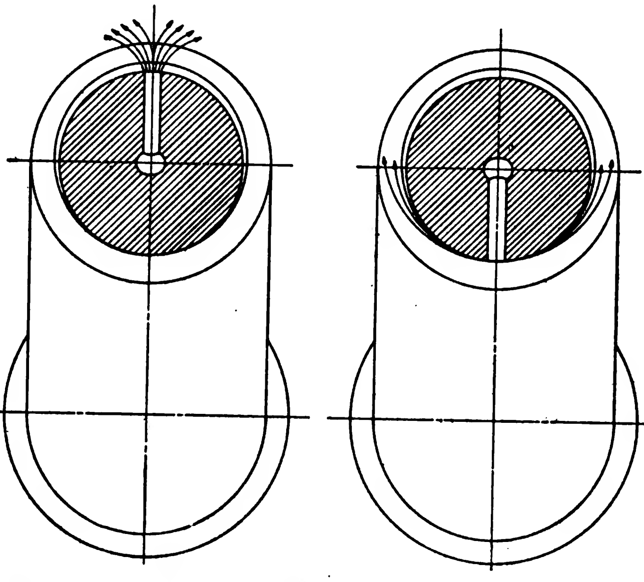


FIG. 18—OIL DISCHARGE FROM A CRANKPIN WITH INSIDE AND OUTSIDE OILHOLES RESPECTIVELY

tained with the different viscosities produced by the control of the temperature when using the same oil, although a slight addition in the consumption is shown with light-bodied oils, which indicates the effect of cylinder-wall temperature and, consequently, the viscosity of the oil on the cylinder walls and the difference in the piston-ring efficiency with the lowered viscosity.

Fig. 19 indicates the relative oil consumption in proportion to viscosities with different oils, *A* being an oil of 500-sec. viscosity at 104 deg. fahr. and *B* an oil of 650-sec. viscosity at 104 deg. fahr. The curve *C* is a portion of a curve prepared by C. W. Stratford, giving the relation between viscosity and oil consumption.

Dilution of the oil by the admixture of liquid fuel is a problem associated with oil consumption. As previously stated, dilution may occur under ordinary operating conditions to the extent that, quantitatively, the fluid in the crankcase is not decreased and the operator assumes that very little oil is being used. The rapid lowering of the viscosity is the dominating influence of dilution which, of course, affects the lubricating value of the oil very considerably and makes it necessary to change the oil

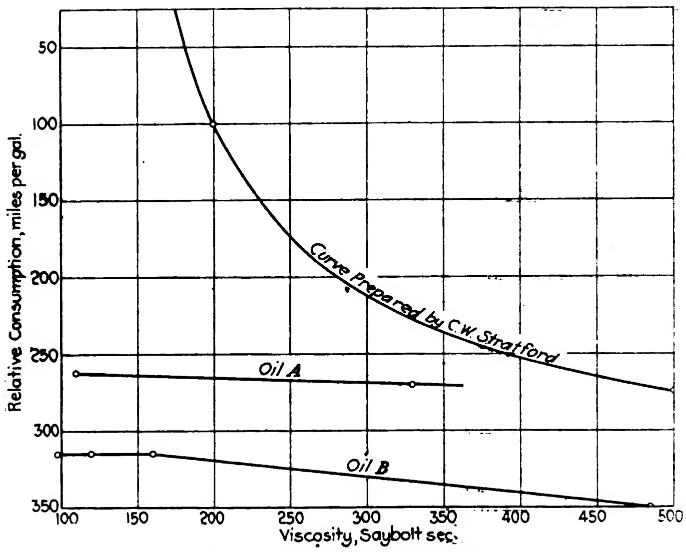


FIG. 19—DIAGRAM SHOWING THE OIL CONSUMPTION WITH RELATION TO THE VISCOSITY AND THE CHARACTER OF THE OIL

frequently to obtain efficient lubrication, unless some one of the types of crankcase-oil refiner that are now being developed is used. The extent of this dilution depends upon many conditions which can, it is believed, be controlled to a large extent.

In the observation of oil consumption and dilution on many engines operating in different parts of the Country, no alarming figures have been obtained, and in very few instances are they in excess of 10 per cent. In the determination of the percentage of dilution, the total quantity of oil or fluid in the reservoir should be known so that, from the percentage of the diluent contained in the sample tested, the total quantity can be computed.

External Oil Leaks and Breather Discharge

External oil leaks are in many cases responsible for excessive oil consumption and often occur at the higher speeds, leaving no direct evidence of the quantity actually lost in this manner. Fog discharged from the breather also has an appreciable influence. This is emphasized particularly where excessive crankpin discharge occurs and also in splash-feed-lubrication engines where light oils are used. Under the latter condition the oil becomes fogged quickly and, if accompanied by piston blow-by, oil vapor will be emitted from the breather.

Controlling the oil pressure in proportion to the throttle opening to effect proportionate lubrication and obtain satisfactory oil economy does not seem to exercise a definite control unless proper consideration is given also to the location of the oil-hole in the crankpin. It is clear that, at the higher speeds, with the increase in the throttle opening and consequently higher pressures, the crankpin discharge will be increased proportionately. It is feasible to use much higher oil pressures with proper oil-hole control which in itself constitutes a favorable argument.

The data presented in this paper cover briefly the general aspect of oil consumption and are supported by actual observations under service conditions. It is believed that the pistons and the rings, when embodying the necessary fundamentals will, in themselves, exercise control over the oil-pumping at the lower speeds and to a definite extent. To insure oil economy under all conditions of operation, it is essential to control the oil supply at its source with a construction that will maintain constant effectiveness.

CHRONICLE AND COMMENT

(*Concluded from page* 444)

In a project and progress chart of highway investigations prepared recently by Doctor Hatt, the four principal classifications are economics of grades, tractive resistance, capital and operating vehicle costs, and construction and maintenance highway costs. Various items of work subsidiary to these classifications are now under way at Iowa State College, University of Michigan, Yale University and Massachusetts Institute of Technology. The matters in connection with which the members of the Society in general are best qualified to serve relate to the establishing of basic items of cost for motor vehicles, including the determination of capital and operating costs for motor trucks, passenger cars and motorbuses. It is expected that there will be general discussion of these subjects at the meeting of the Society to be held at White Sulphur Springs this month.

Road-Service Fuel Tests

FOLLOWING a series of tests, recently run by the Bureau of Standards, showing a consistent change in fuel-consumption with fuel volatility, the Research Department of the Society arranged for the conduct of similar tests by several automobile builders. The following organizations are participating in this work:

Buick Motor Co.
Packard Motor Car Co.
Hupp Motor Car Co.
Studebaker Corporation of America
Chevrolet Motor Car Co.
International Harvester Co.
Stromberg Motor Devices Co.
Dodge Bros.

Other companies will start making the tests as soon as an additional supply of the special fuels prepared for the purpose is available.

The tests are intended to show what effect, under normal everyday running conditions with average drivers, distinct differences in fuel volatility have on the total amount of fuel used per mile of travel. The main feature of the tests is the operation of a number of cars of each of several models by their regular drivers in the course of their ordinary driving, but each car being supplied successively for periods of 1 week's duration with fuels differing by definite steps in volatility characteristics. An essential point is that the drivers are not informed as to the grade of fuel they are using at any time. The tests will not interfere in the slightest degree with the regular service of any of the cars further than to permit the filling and draining of the fuel-tanks during the test for checking the consumption.

Copies of all the records are to be forwarded to the Society's Research Department for compilation and comparison. The final results of the tests are to be used to estimate the effect of fuel changes on the total fuel-consumption of the Country.

A joint test program, including elaborate road tests of vehicles and far-reaching fuel investigations, is to be conducted by the Bureau of Standards, the Bureau of Mines, and other government agencies, with the support and cooperation of the National Automobile Chamber of Commerce and the Society of Automotive Engineers, representing the automotive industries, and the American Petroleum Institute, representing the petroleum industry. The tests are under the general supervision of the Research Department of the Society of Automotive Engineers and the Research Division of the American Petroleum Institute.

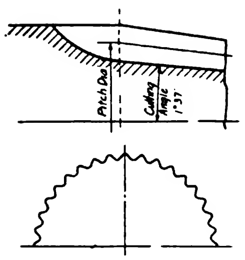
When the tests are completed, and the information derived has been compiled, it will be possible to state more exactly what grade of gasoline should be distilled and sold to the public to conserve the petroleum resources of the Country, and at the same time provide the public with a grade of gasoline that will give good mileage at a reasonable price.

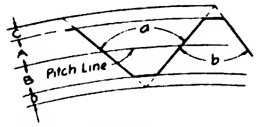
REPORTS OF DIVISIONS TO STANDARDS COMMITTEE

(*Concluded from page* 488)

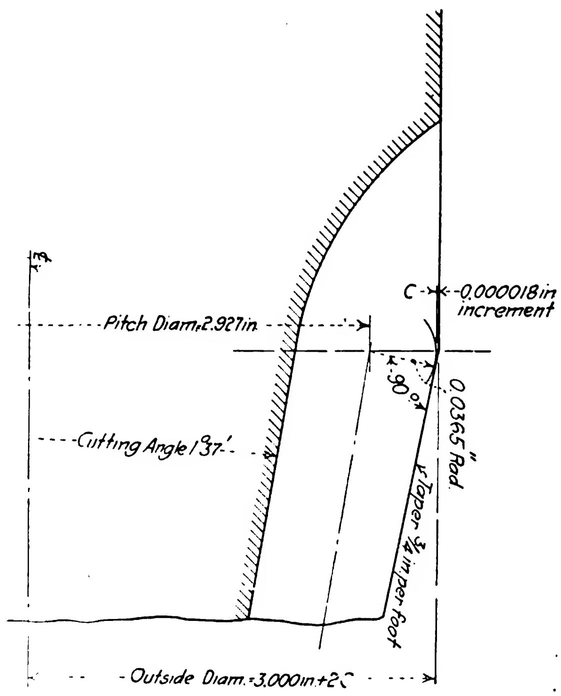
Nominal Diam.	Pitch Diam. Max.	Pitch Diam. Min.	*N*	*a*, deg.	*b*, deg.	HOLE Large Diam. Min.	HOLE Small Diam. Max.	HOLE Small Diam. Min.	SHAFT Outside Diam. Max.	SHAFT Outside Diam. Min.	SHAFT Inside Diam. Max.
½	0.485	0.483	36	90	80	0.500	0.469	0.468	0.499	0.498	0.467
⅝	0.605	0.603	36	90	80	0.625	0.584	0.583	0.624	0.623	0.582
¾	0.733	0.731	36	90	80	0.750	0.716	0.714	0.749	0.747	0.713
⅞	0.855	0.853	36	90	80	0.875	0.835	0.833	0.874	0.872	0.832
1	0.977	0.975	36	90	80	1.000	0.954	0.952	0.999	0.997	0.951
1⅛	1.098	1.096	36	90	80	1.125	1.071	1.069	1.124	1.122	1.068
1¼	1.220	1.218	36	90	80	1.250	1.190	1.188	1.249	1.247	1.187
1⅜	1.342	1.340	36	90	80	1.375	1.309	1.307	1.374	1.372	1.306
1½	1.464	1.462	36	90	80	1.500	1.428	1.426	1.499	1.497	1.425
1¾	1.708	1.706	36	90	80	1.750	1.666	1.664	1.749	1.747	1.663
2	1.952	1.949	48	90	82½	2.000	1.904	1.902	1.999	1.997	1.901
2¼	2.196	2.193	48	90	82½	2.250	2.142	2.140	2.249	2.247	2.139
2½	2.440	2.437	48	90	82½	2.500	2.380	2.378	2.499	2.497	2.377
2¾	2.684	2.681	48	90	82½	2.750	2.618	2.616	2.749	2.747	2.615
3	2.928	2.925	48	90	82½	3.000	2.856	2.854	2.999	2.997	2.853

All dimensions in inches and apply to large end of taper only.
Taper ¾ in. per ft. on outside diameter.
Cutting Angle 1 deg. 37 min.





A and B are Nominally Equal at Large End Only
A + B = Depth of Cut
C in Hole and D in Shaft may be made as desired by each individual manufacturer beyond min and max as specified in table
N = Number of Serrations
Length of Full Serration on Shaft = Normal Dia



of gasoline-tank filler-pipe openings on automobiles and motor-trucks. This matter was referred to the Parts and Fittings Division for consideration in connection with the present S.A.E. Recommended Practice for Tank and Radiator Caps, page 650 of the S.A.E. HANDBOOK. It developed that the filler-pipe openings are in most cases 2 in. or larger in diameter and that a 2-in. minimum opening is acceptable. Therefore

The Parts and Fittings Division recommends that the present S.A.E. Recommended Practice for Tank and Radiator Caps, page C58 of the S.A.E. HANDBOOK, be extended by adding the note, "It is recommended that on passenger-cars, motor-trucks and tractors gasoline-tank filler-pipes have a minimum clear opening of 2 in. in diameter"

Lock-Washers

(Proposed Extension of S.A.E. Standard)

At the meeting of the Parts and Fittings Division on May 9 attention of the members was called to the trouble that had been experienced due to the lack of temper or to the brittleness of the lock-washers. The members of the Division felt that the temper and toughness tests which were included in the S.A.E. Standard previous to the adoption of the last revision, should be included in the present standard to provide an adequate check on the quality of lock-washers in guarding against the troubles that have been experienced. Therefore

The Parts and Fittings Division recommends that the present S.A.E. Standard, page C5 of the S.A.E. Handbook, be extended to include the accompanying temper and toughness tests.

Temper Test. — After compressing the lock-washer to flat, the reaction shall be sufficient to indicate necessary spring power, and on a subsequent compression to flat the lock-washer shall manifest no appreciable loss in reaction

Toughness Test.—Forty-five per cent of the lock-washer, including one end, shall be secured firmly in a vise, and 45 per cent, including the other end, shall be secured firmly between parallel jaws of a wrench. Movement of wrench at right angles to the helical curve shall twist the lock-washer through 45 deg. without it showing signs of fracturing, and shall twist the lock-washer entirely apart within 135 deg.

SCREW THREADS DIVISION REPORT

Division Personnel

E. H. Ehrman, *Chairman*	Chicago Screw Co.
O. B. Zimmerman, *Vice-Chairman*	International Harvester Co.
Earle Buckingham	Pratt & Whitney Co.
E. Burdsall	Russell, Burdsall & Ward Bolt & Nut Co.
Luther Burlingame	Brown & Sharpe Co.
G. S. Case	Lamson & Sessions Co.
W. R. Mitchell	National Acme Mfg. Co.
Alex Taub	General Motors Corporation

Screw Threads

(Proposed Extension of S.A.E. Standard)

At the meeting of the Miscellaneous Division in Cleveland in December 1916 the proposal to standardize screw-thread tolerances was first considered. Not much progress was made, however, for some little time. E. H. Ehrman, who was a member of the Division and also of the American Society of Mechanical Engineers Committee working on this subject, conducted a number of tests in connection with the work. The National Screw Thread Commission having been created by Congress in July 1918 the Miscellaneous Division concluded that it would be better to defer the formulation of a Division report pending a report by the Commission, in order not to parallel the work of that body and possibly cause confusion. Mr. Ehrman, who was chairman of the Miscellaenous Division, was appointed by the Society as one of its representatives on the Commission.

In May 1919 the Commission issued a tentative report that included in general the classification of fits and the detailed dimensions for the screw threads included under the several classes of fit. The Society was requested to review the progress report of the Commission and make suggestions regarding those parts of it that would be applicable to automotive apparatus. A meeting held in New York City of Sept. 8, 1919, was attended by representatives of screw-thread parts producers and users, the American Society of Mechanical Engineers, the Bureau of Standards and members of the National Screw Thread Commission. General discussion of the Commission's progress report indicated the desirability of further investigating the application of its provisions in the automotive industries, and a special Society Committee was appointed for this purpose, consisting of

Paul W. Abbot, *Chairman*	Lincoln Motor Co.
W. K. Jamison	Domestic Engineering Co.
B. P. Smith	Packard Motor Car Co.
Lyle K. Snell	Willys-Overland Co.
Alex Taub	General Motors Corporation

This Committee wrote more than 200 representative companies engaged in automotive work for data as to their current screw-thread practice. The Society was assisted in securing returns to the questionnaire by the National Automobile Chamber of Commerce, the Motor & Accessory Manufacturers Association and the National Gas Engine Association.

The special Committee issued its report to the Society on Jan. 3, 1920, and it was transmitted to and duly considered by the National Screw Thread Commission in preparing its progress report of June 1920.

The Miscellaneous Division of the Standards Committee had been kept informed by its chairman and the Society of the progress that had been made in this work. Meantime a Sectional Committee had been formed, which was sponsored by the Society and the American Society of Mechanical Engineers for further study of the National Screw Thread Commission's progress report toward its adoption by the mechanical industries in general. The Division felt that the Society should not adopt specific data in connection with screw-thread fits and dimensions until the work in progress by the Sectional Committee indicated approval of the National Screw Thread Commission's report. The Sectional Committee referred the report of the Commission to a Working Committee of the Sectional Committee, which reported in February 1922, having made the following selections from and changes in the Commission's report:

(1) Certain combinations of thread series and fit have been selected as suitable for general use. The coarse-thread close fit has been omitted. It is recommended that the loose-fit tolerances be published separately

(2) Classes of fit have been renumbered to eliminate the Subdivision of the Commission's Class II

(3) The material relating to gaging has been omitted, with the recommendation that it be developed and published separately

(4) The pipe-thread standard has been omitted, since it has already been approved as an American standard and published by the A.E.S.C.

(5) Fire hose and regular hose standards have been omitted. The publication of these as a separate pamphlet is recommended

(6) The Fine-Thread Series (S.A.E.) has not been carried beyond 1½ in. 12 pitch

(7) The relation between lead or form errors and pitch-diameter tolerances has been treated in detail

(8) Extreme or drawing tolerances only are given

(9) The material has been generally condensed and somewhat rearranged

In January 1920 the Screw Threads Division of the Standards Committee was organized to consider all

screw-thread standardization matters for the Society, and took over the former work of the Miscellaneous Division. No separate action was taken on the work before the National Screw Thread Commission by the Screw Threads Division toward establishing an S.A.E. Standard for screw-thread dimensions, pending the conclusion of the National Screw Thread Commission and the Sectional Committee's work. With the completion of the report of the Working Committee of the Sectional Committee in February of this year, the Division felt that the Society could properly proceed to adopt the classification of fits and tables of dimensions for screw threads which are used by the automotive industries, and now recommends that the following definitions and tables, taken from the report of the Working Committee of the Sectional Committee, be adopted as S.A.E. Standard.

The Working Committee's report is still to be approved by the Society and the American Society of Mechanical Engineers as sponsors for the Sectional Committee, organized under the rules of the American Engineering Standards Committee, but the Division members feel that the following recommendations can now be adopted by the Society. Therefore

The Screw Threads Division recommends that the present S.A.E. Standard for Screw-Threads, page C1 of the S.A.E. HANDBOOK, be extended to include the accompanying Tables Nos. 1 to 7 inclusive, together with the definitions.

Class II B—Medium Fit.—This class of screw-threads shall be defined and specified as follows:

(1) Minimum Nut is Basic
(2) Maximum Screw is Basic
(3) Direction of Tolerance on Nut. The tolerance on the nut shall be plus
(4) Direction of Tolerance on Screw. The tolerance on the screw shall be minus
(5) Zero Allowance. The allowance between the pitch diameter of the maximum screw and the minimum nut shall be zero for all pitches and all diameters
(6) Tolerance Values. The tolerances for a screw or nut of a given pitch shall be as specified in table 3.

Class II A—Free Fit.—This class of screw-threads shall be defined and specified as follows:

(1) Minimum Nut is Basic
(2) Maximum Screw is Basic
(3) Direction of Tolerance on Nut. The tolerance on the nut shall be plus
(4) Direction of Tolerance on Screw. The tolerance on the screw shall be minus
(5) Zero Allowance. The allowance between the

TABLE 1—ALLOWANCES AND TOLERANCES FOR SCREWS AND NUTS, CLASS IIA, FREE FIT

Threads Per In.	Allowance, In.	Pitch-Diameter Tolerances, In.	Lead,[1] In.	Half Angle, min. sec.
80	0.0000	0.0017	0.0005	2—50
72	0.0000	0.0018	0.0005	2—41
64	0.0000	0.0019	0.0005	2—23
56	0.0000	0.0020	0.0006	2—11
48	0.0000	0.0022	0.0006	2—04
44	0.0000	0.0023	0.0007	2—03
40	0.0000	0.0024	0.0007	1—52
36	0.0000	0.0025	0.0007	1—49
32	0.0000	0.0027	0.0008	1—41
28	0.0000	0.0031	0.0009	1—45
24	0.0000	0.0033	0.0009	1—32
20	0.0000	0.0036	0.0010	1—24
18	0.0000	0.0041	0.0012	1—26
16	0.0000	0.0045	0.0013	1—24
14	0.0000	0.0049	0.0014	1—20
13	0.0000	0.0052	0.0015	1—19
12	0.0000	0.0056	00.016	1—18
11	0.0000	0.0059	0.0017	1—15
10	0.0000	0.0064	0.0018	1—14
9	0.0090	0.0070	0.0020	1—13
8	0.0000	0.0076	0.0022	1—11
7	0.0000	0.0085	0.0024	1—09
6	0.0000	0.0101	0.0029	1—10
5	0.0000	0.0116	0.0033	1—07
4½	0.0000	0.0127	0.0037	1—06
4	0.0000	0.0140	0.0040	1—05

[1] Variation in lead between any two threads not farther apart than the length of engagement.

The tolerances specified for the pitch diameters are cumulative and include all errors of lead and angle. The full tolerance on the pitch diameter is therefore not available unless the lead and the angle of the thread are perfect. The last two columns give as general information the error in lead, per length of thread engaged, and in angle respectively that can each be compensated for by half the tolerance on the pitch diameter. If the lead and the angle error both exist to the amount tabulated, the pitch diameter of a bolt, for example, must be reduced by the full tolerance or it will not enter a basic nut or gage. If no lead error existed on such a bolt, the angle error could be twice that given, and conversely; but these extreme conditions are not contemplated as being desirable.

TABLE 2—ALLOWANCES AND TOLERANCES FOR SCREWS AND NUTS CLASS IIB, MEDIUM FIT

Threads Per In.	Allowance, In.	Pitch-Diameter Tolerances, In.	Lead,[1] In.	Half Angle, min. sec.
80	0.0000	0.0013	0.0004	2—07
72	0.0000	0.0013	0.0004	1—54
64	0.0000	0.0014	0.0004	1—49
56	0.0000	0.0015	0.0004	1—41
48	0.0000	0.0016	0.0005	1—32
44	0.0000	0.0016	0.0005	1—24
40	0.0000	0.0017	0.0005	1—21
36	0.0000	0.0018	0.0005	1—17
32	0.0000	0.0019	0.0005	1—12
28	0.0000	0.0022	0.0006	1—13
24	0.0000	0.0024	0.0007	1—08
20	0.0000	0.0026	0.0008	1—02
18	0.0000	0.0030	0.0009	1—04
16	0.0000	0.0032	0.0009	1—01
14	0.0000	0.0036	0.0010	1—00
13	0.0000	0.0037	0.0011	0—57
12	0.0000	0.0040	0.0012	0—57
11	0.0000	0.0042	0.0012	0—55
10	0.0000	0.0045	0.0013	0—54
9	0.0000	0.0049	0.0014	0—52
8	0.0000	0.0054	0.0016	0—51
7	0.0000	0.0059	0.0017	0—49
6	0.0000	0.0071	0.0020	0—50
5	0.0000	0.0082	0.0024	0—48
4½	0.0000	0.0089	0.0026	0—47
4	0.0000	0.0097	0.0028	0—46

[1] Variation in lead between any two threads not farther apart than the length of engagement.

The tolerances specified for the pitch diameters are cumulative and include all errors of lead and angle. The full tolerance on the pitch diameter is therefore not available unless the lead and the angle of the thread are perfect. The last two columns give as general information the error in lead, per length of thread engaged, and in angle respectively that can each be compensated for by half the tolerance on the pitch diameter. If the lead and the angle error both exist to the amount tabulated, the pitch diameter of a bolt, for example, must be reduced by the full tolerance or it will not enter a basic nut or gage. If no lead error existed on such a bolt, the angle error could be twice that given, and conversely; but these extreme conditions are not contemplated as being desirable.

TABLE 3—CLASS IIA, FREE FIT, FOR SCREWS OF THE COARSE THREAD SERIES

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Minor Diameter		
		Max.[1]	Tolerance	Min.	Max.[1]	Tolerance[2]	Min.	Max.[3]	Tolerance	Min.
1	64	0.0730	0.0038	0.0692	0.0629	0.0019	0.0610	0.0538	0.0030	0.0508
2	56	0.0860	0.0040	0.0820	0.0744	0.0020	0.0724	0.0641	0.0033	0.0608
3	48	0.0990	0.0044	0.0946	0.0855	0.0022	0.0833	0.0754	0.0037	0.0697
4	40	0.1120	0.0048	0.1072	0.0958	0.0024	0.0934	0.0813	0.0042	0.0771
5	40	0.1250	0.0048	0.1202	0.1088	0.0024	0.1064	0.0943	0.0042	0.0901
6	32	0.1380	0.0054	0.1326	0.1177	0.0027	0.1150	0.0997	0.0050	0.0947
8	32	0.1640	0.0054	0.1586	0.1437	0.0027	0.1410	0.1257	0.0050	0.1207
10	24	0.1900	0.0066	0.1834	0.1629	0.0033	0.1596	0.1389	0.0063	0.1326
12	24	0.2160	0.0066	0.2094	0.1889	0.0033	0.1856	0.1649	0.0063	0.1586
1/4	20	0.2500	0.0072	0.2428	0.2175	0.0036	0.2139	0.1887	0.0073	0.1814
5/16	18	0.3125	0.0082	0.3043	0.2764	0.0041	0.2723	0.2443	0.0081	0.2362
3/8	16	0.3750	0.0090	0.3660	0.3344	0.0045	0.3299	0.2983	0.0090	0.2893
7/16	14	0.4375	0.0098	0.4277	0.3911	0.0049	0.3862	0.3499	0.0101	0.3398
1/2	13	0.5000	0.0104	0.4896	0.4500	0.0052	0.4448	0.4056	0.0107	0.3949
9/16	12	0.5625	0.0112	0.5513	0.5084	0.0056	0.5028	0.4603	0.0117	0.4486
5/8	11	0.6250	0.0118	0.6132	0.5660	0.0059	0.5601	0.5135	0.0125	0.5010
3/4	10	0.7500	0.0128	0.7372	0.6850	0.0064	0.6786	0.6273	0.0136	0.6137
7/8	9	0.8750	0.0140	0.8610	0.8028	0.0070	0.7958	0.7387	0.0150	0.7237
1	8	1.0000	0.0152	0.9848	0.9188	0.0076	0.9112	0.8466	0.0166	0.8300
1 1/8	7	1.1250	0.0170	1.1080	1.0322	0.0085	1.0287	0.9497	0.0188	0.9309
1 1/4	7	1.2500	0.0170	1.2330	1.1572	0.0085	1.1487	1.0747	0.0188	1.0559
1 1/2	6	1.5000	0.0202	1.4798	1.3917	0.0101	1.3816	1.2955	0.0219	1.2734
1 3/4	5	1.7500	0.0232	1.7268	1.6201	0.0116	1.6085	1.5046	0.0260	1.4786
2	4 1/2	2.0000	0.0254	1.9746	1.8557	0.0127	1.8430	1.7274	0.0288	1.6986
2 1/4	4 1/2	2.2500	0.0254	2.2246	2.1057	0.0127	2.0930	1.9774	0.0288	1.9486
2 1/2	4	2.5000	0.0280	2.4720	2.3376	0.0140	2.3236	2.1933	0.0321	2.1612
2 3/4	4	2.7500	0.0280	2.7220	2.5876	0.0140	2.5736	2.4433	0.0321	2.4112
3	4	3.0000	0.0280	2.9720	2.8376	0.0140	2.8236	2.6933	0.0321	2.6612

TABLE 4—CLASS IIA, FREE FIT, FOR NUTS OF THE COARSE THREAD SERIES

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Minor Diameter		
		Min.[2]	Tolerance	Max.	Min.[1]	Tolerance[3]	Max.	Min.	Tolerance	Max.
1	64	0.0741	0.0031	0.0772	0.0629	0.0019	0.0648	0.0561	0.0017	0.0578
2	56	0.0873	0.0033	0.0906	0.0744	0.0020	0.0764	0.0667	0.0019	0.0686
3	48	0.1005	0.0037	0.1042	0.0855	0.0022	0.0877	0.0764	0.0023	0.0787
4	40	0.1138	0.0042	0.1180	0.0958	0.0024	0.0982	0.0849	0.0027	0.0876
5	40	0.1268	0.0042	0.1310	0.1088	0.0024	0.1112	0.0979	0.0027	0.1006
6	32	0.1403	0.0049	0.1452	0.1177	0.0027	0.1204	0.1042	0.0034	0.1076
8	32	0.1663	0.0049	0.1712	0.1437	0.0027	0.1464	0.1302	0.0034	0.1336
10	24	0.1930	0.0063	0.1993	0.1629	0.0033	0.1662	0.1449	0.0045	0.1494
12	24	0.2190	0.0063	0.2253	0.1889	0.0033	0.1922	0.1709	0.0045	0.1754
1/4	20	0.2536	0.0072	0.2608	0.2175	0.0036	0.2211	0.1959	0.0054	0.2013
5/16	18	0.3165	0.0081	0.3246	0.2764	0.0041	0.2805	0.2524	0.0060	0.2584
3/8	16	0.3795	0.0090	0.3885	0.3344	0.0045	0.3389	0.3073	0.0068	0.3141
7/16	14	0.4427	0.0100	0.4527	0.3911	0.0049	0.3960	0.3602	0.0077	0.3679
1/2	13	0.5056	0.0107	0.5163	0.4500	0.0052	0.4552	0.4167	0.0084	0.4251
9/16	12	0.5685	0.0116	0.5801	0.5084	0.0056	0.5140	0.4723	0.0090	0.4813
5/8	11	0.6316	0.0124	0.6440	0.5660	0.0059	0.5719	0.5266	0.0098	0.5364
3/4	10	0.7572	0.0136	0.7708	0.6850	0.0064	0.6914	0.6417	0.0109	0.6526
7/8	9	0.8830	0.0150	0.8980	0.8028	0.0070	0.8098	0.7547	0.0120	0.7667
1	8	1.0090	0.0166	1.0256	0.9188	0.0076	0.9264	0.8647	0.0135	0.8782
1 1/8	7	1.1353	0.0188	1.1541	1.0322	0.0085	1.0407	0.9704	0.0154	0.9858
1 1/4	7	1.2603	0.0188	1.2791	1.1572	0.0085	1.1657	1.0954	0.0154	1.1108
1 1/2	6	1.5120	0.0222	1.5342	1.3917	0.0101	1.4018	1.3196	0.0180	1.3376
1 3/4	5	1.7644	0.0261	1.7905	1.6201	0.0116	1.6317	1.5335	0.0216	1.5551
2	4 1/2	2.0160	0.0288	2.0448	1.8557	0.0127	1.8684	1.7594	0.0241	1.7835
2 1/4	4 1/2	2.2660	0.0288	2.2948	2.1057	0.0127	2.1184	2.0094	0.0241	2.0335
2 1/2	4	2.5180	0.0321	2.5501	2.3376	0.0140	2.3516	2.2294	0.0270	2.2564
2 3/4	4	2.7680	0.0321	2.8001	2.5876	0.0140	2.6016	2.4794	0.0270	2.5064
3	4	3.0180	0.0321	3.0501	2.8376	0.0140	2.8516	2.7294	0.0270	2.7564

See page 528 for footnotes.

TABLE 5—CLASS IIB, MEDIUM FIT, FOR SCREWS OF THE COARSE THREAD SERIES

Size	Threads Per Inch	Major Diameter, in. Max.[1]	Major Diameter, in. Tolerance	Major Diameter, in. Min.	Pitch Diameter, in. Max.[1]	Pitch Diameter, in. Tolerance[3]	Pitch Diameter, in. Min.	Minor Diameter, in. Max.[2]	Minor Diameter, in. Tolerance	Minor Diameter, in. Min.
1	64	0.0730	0.0028	0.0702	0.0629	0.0014	0.0615	0.0538	0.0025	0.0513
2	56	0.0860	0.0030	0.0830	0.0744	0.0015	0.0729	0.0641	0.0028	0.0613
3	48	0.0990	0.0032	0.0958	0.0855	0.0016	0.0839	0.0734	0.0031	0.0703
4	40	0.1120	0.0034	0.1086	0.0958	0.0017	0.0941	0.0813	0.0035	0.0778
5	40	0.1250	0.0034	0.1216	0.1088	0.0017	0.1071	0.0943	0.0035	0.0908
6	32	0.1380	0.0038	0.1342	0.1177	0.0019	0.1158	0.0997	0.0042	0.0955
8	32	0.1640	0.0038	0.1602	0.1437	0.0019	0.1418	0.1257	0.0042	0.1215
10	24	0.1900	0.0048	0.1852	0.1629	0.0024	0.1605	0.1389	0.0054	0.1335
12	24	0.2160	0.0048	0.2112	0.1889	0.0024	0.1865	0.1649	0.0054	0.1595
¼	20	0.2500	0.0052	0.2448	0.2175	0.0026	0.2149	0.1887	0.0063	0.1824
5/16	18	0.3125	0.0060	0.3065	0.2764	0.0030	0.2734	0.2443	0.0070	0.2373
⅜	16	0.3750	0.0064	0.3686	0.3344	0.0032	0.3312	0.2983	0.0076	0.2906
7/16	14	0.4375	0.0072	0.4303	0.3911	0.0036	0.3875	0.3499	0.0088	0.3411
½	13	0.5000	0.0074	0.4926	0.4500	0.0037	0.4463	0.4056	0.0092	0.3964
9/16	12	0.5625	0.0080	0.5545	0.5084	0.0040	0.5044	0.4603	0.0101	0.4502
⅝	11	0.6250	0.0084	0.6166	0.5660	0.0042	0.5618	0.5135	0.0108	0.5027
¾	10	0.7500	0.0090	0.7410	0.6850	0.0045	0.6805	0.6273	0.0117	0.6156
⅞	9	0.8750	0.0098	0.8652	0.8028	0.0049	0.7979	0.7387	0.0129	0.7258
1	8	1.0000	0.0108	0.9892	0.9188	0.0054	0.9134	0.8466	0.0144	0.8322
1⅛	7	1.1250	0.0118	1.1132	1.0322	0.0059	1.0263	0.9497	0.0162	0.9335
1¼	7	1.2500	0.0118	1.2382	1.1572	0.0059	1.1513	1.0747	0.0162	1.0585
1½	6	1.5000	0.0142	1.4858	1.3917	0.0071	1.3846	1.2955	0.0191	1.2764
1¾	5	1.7500	0.0164	1.7336	1.6201	0.0082	1.6119	1.5056	0.0216	1.4820
2	4½	2.0000	0.0178	1.9822	1.8557	0.0089	1.8468	1.7274	0.0250	1.7024
2¼	4½	2.2500	0.0178	2.2322	2.1057	0.0089	2.0968	1.9774	0.0250	1.9524
2½	4	2.5000	0.0194	2.4806	2.3376	0.0097	2.3279	2.1933	0.0278	2.1655
2¾	4	2.7500	0.0194	2.7306	2.5876	0.0097	2.5779	2.4433	0.0278	2.4155
3	4	3.0000	0.0194	2.9806	2.8376	0.0097	2.8279	2.6933	0.0278	2.6655

TABLE 6—CLASS IIB, MEDIUM FIT, FOR NUTS OF THE COARSE THREAD SERIES

Size	Threads Per Inch	Major Diameter Min.[2]	Major Diameter Tolerance	Major Diameter Max.	Pitch Diameter Min.[1]	Pitch Diameter Tolerance[3]	Pitch Diameter Max.	Minor Diameter Min.	Minor Diameter Tolerance	Minor Diameter Max.
1	64	0.0741	0.0026	0.0767	0.0629	0.0014	0.0643	0.0561	0.0017	0.0578
2	56	0.0873	0.0028	0.0901	0.0744	0.0015	0.0759	0.0667	0.0019	0.0686
3	48	0.1005	0.0031	0.1036	0.0855	0.0016	0.0871	0.0764	0.0023	0.0787
4	40	0.1138	0.0035	0.1173	0.0958	0.0017	0.0975	0.0949	0.0027	0.0876
5	40	0.1268	0.0035	0.1303	0.1088	0.0017	0.1105	0.0979	0.0027	0.1006
6	32	0.1403	0.0041	0.1444	0.1177	0.0019	0.1196	0.1042	0.0034	0.1076
8	32	0.1663	0.0041	0.1704	0.1437	0.0019	0.1456	0.1302	0.0034	0.1336
10	24	0.1930	0.0054	0.1984	0.1629	0.0024	0.1653	0.1449	0.0045	0.1494
12	24	0.2190	0.0054	0.2244	0.1889	0.0024	0.1913	0.1709	0.0045	0.1754
¼	20	0.2536	0.0062	0.2598	0.2175	0.0026	0.2201	0.1959	0.0054	0.2013
5/16	18	0.3165	0.0070	0.3235	0.2764	0.0030	0.2794	0.2524	0.0060	0.2584
⅜	16	0.3795	0.0077	0.3872	0.3344	0.0032	0.3376	0.3073	0.0068	0.3141
7/16	14	0.4427	0.0087	0.4514	0.3911	0.0036	0.3947	0.3602	0.0077	0.3679
½	13	0.5056	0.0092	0.5148	0.4500	0.0037	0.4537	0.4167	0.0084	0.4251
9/16	12	0.5685	0.0100	0.5785	0.5084	0.0040	0.5124	0.4723	0.0090	0.4813
⅝	11	0.6316	0.0107	0.6423	0.5660	0.0042	0.5702	0.5266	0.0098	0.5364
¾	10	0.7572	0.0117	0.7689	0.6850	0.0045	0.6895	0.6417	0.0109	0.6526
⅞	9	0.8830	0.0129	0.8959	0.8028	0.0049	0.8077	0.7547	0.0120	0.7667
1	8	1.0090	0.0144	1.0234	0.9188	0.0054	0.9242	0.8647	0.0135	0.8782
1⅛	7	1.1353	0.0162	1.1515	1.0322	0.0059	1.0381	0.9704	0.0154	0.9858
1¼	7	1.2603	0.0162	1.2765	1.1572	0.0059	1.1631	1.0954	0.0154	1.1108
1½	6	1.5120	0.0192	1.5312	1.3917	0.0071	1.3988	1.3196	0.0180	1.3376
1¾	5	1.7644	0.0227	1.7871	1.6201	0.0082	1.6283	1.5335	0.0216	1.5551
2	4½	2.0160	0.0250	2.0410	1.8557	0.0089	1.8646	1.7594	0.0241	1.7835
2¼	4½	2.2660	0.0250	2.2910	2.1057	0.0089	2.1146	2.0094	0.0241	2.0335
2½	4	2.5180	0.0278	2.5458	2.3376	0.0097	2.3473	2.2294	0.0270	2.2564
2¾	4	2.7680	0.0278	2.7958	2.5876	0.0097	2.5973	2.4794	0.0270	2.5064
3	4	3.0180	0.0278	3.0458	2.8376	0.0097	2.8473	2.7294	0.0270	2.7564

See page 528 for footnotes.

TABLE 7—CLASS IIA, FREE FIT, FOR SCREWS OF THE FINE THREAD SERIES

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Minor Diameter		
		Max.[1]	Toler-ance	Min.	Max.[1]	Toler-ance[3]	Min.	Max[2]	Toler-ance	Min.
0	80	0.0600	0.0034	0.0566	0.0519	0.0017	0.0502	0.0447	0.0026	0.0421
1	72	0.0730	0.0036	0.0694	0.0640	0.0018	0.0622	0.0560	0.0028	0.0532
2	64	0.0860	0.0038	0.0822	0.0759	0.0019	0.0740	0.0668	0.0030	0.0638
3	56	0.0990	0.0040	0.0950	0.0874	0.0020	0.0854	0.0771	0.0033	0.0738
4	48	0.1120	0.0044	0.1076	0.0985	0.0022	0.0963	0.0864	0.0037	0.0827
5	44	0.1250	0.0046	0.1204	0.1102	0.0023	0.1079	0.0971	0.0039	0.0932
6	40	0.1380	0.0048	0.1332	0.1218	0.0024	0.1194	0.1073	0.0042	0.1031
8	36	0.1640	0.0050	0.1590	0.1460	0.0025	0.1435	0.1299	0.0045	0.1254
10	32	0.1900	0.0054	0.1846	0.1697	0.0027	0.1670	0.1517	0.0050	0.1467
12	28	0.2160	0.0062	0.2098	0.1928	0.0031	0.1897	0.1722	0.0057	0.1665
¼	28	0.2500	0.0062	0.2438	0.2268	0.0031	0.2237	0.2062	0.0057	0.2005
5/16	24	0.3125	0.0066	0.3059	0.2854	0.0033	0.2821	0.2614	0.0063	0.2551
⅜	24	0.3750	0.0066	0.3684	0.3479	0.0033	0.3446	0.3239	0.0063	0.3176
7/16	20	0.4375	0.0072	0.4303	0.4050	0.0036	0.4014	0.3762	0.0073	0.3689
½	20	0.5000	0.0072	0.4928	0.4675	0.0036	0.4639	0.4387	0.0073	0.4314
9/16	18	0.5625	0.0082	0.5543	0.5264	0.0041	0.5243	0.4943	0.0081	0.4862
⅝	18	0.6250	0.0082	0.6168	0.5889	0.0041	0.5848	0.5568	0.0081	0.5487
¾	16	0.7500	0.0090	0.7410	0.7094	0.0045	0.7049	0.6733	0.0090	0.6643
⅞	14	0.8750	0.0098	0.8652	0.8286	0.0049	0.8237	0.7874	0.0101	0.7733
1	14	1.0000	0.0098	0.9902	0.9536	0.0049	0.9487	0.9124	0.0101	0.9023
1⅛	12	1.1250	0.0112	1.1138	1.0709	0.0056	1.0653	1.0228	0.0117	1.0111
1¼	12	1.2500	0.0112	1.2388	1.1959	0.0056	1.1903	1.1478	0.0117	1.1361
1½	12	1.5000	0.0112	1.4888	1.4459	0.0056	1.4403	1.3978	0.0117	1.3861

[1] Basic diameters.
[2] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root.
[3] The tolerances specified for the pitch diameter are cumulative and include all errors of lead and angle.

TABLE 8—CLASS IIA, FREE FIT, FOR NUTS OF THE FINE THREAD SERIES

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Minor Diameter		
		Min.[2]	Toler-ance	Max.	Min.[1]	Toler-ance[3]	Max.	Min.	Toler-ance	Max.
0	80	0.0609	0.0024	0.0635	0.0519	0.0017	0.0536	0.0465	0.0013	0.0478
1	72	0.0740	0.0028	0.0768	0.0640	0.0018	0.0658	0.0580	0.0015	0.0595
2	64	0.0871	0.0031	0.0902	0.0759	0.0019	0.0778	0.0691	0.0017	0.0708
3	56	0.1003	0.0033	0.1036	0.0874	0.0020	0.0894	0.0797	0.0019	0.0816
4	48	0.1135	0.0037	0.1172	0.0985	0.0022	0.1007	0.0894	0.0023	0.0917
5	44	0.1266	0.0040	0.1306	0.1102	0.0023	0.1125	0.1004	0.0025	0.1029
6	40	0.1398	0.0042	0.1440	0.1218	0.0024	0.1242	0.1109	0.0027	0.1136
8	36	0.1660	0.0045	0.1705	0.1460	0.0025	0.1485	0.1339	0.0030	0.1369
10	32	0.1923	0.0049	0.1972	0.1697	0.0027	0.1724	0.1562	0.0034	0.1596
12	28	0.2186	0.0057	0.2243	0.1928	0.0031	0.1959	0.1773	0.0039	0.1812
¼	28	0.2526	0.0057	0.2583	0.2268	0.0031	0.2299	0.2113	0.0039	0.2152
5/16	24	0.3155	0.0063	0.3218	0.2854	0.0033	0.2887	0.2674	0.0045	0.2719
⅜	24	0.3780	0.0063	0.3843	0.3479	0.0033	0.3512	0.3299	0.0045	0.3344
7/16	20	0.4411	0.0072	0.4483	0.4050	0.0036	0.4086	0.3834	0.0054	0.3888
½	20	0.5036	0.0072	0.5108	0.4675	0.0036	0.4711	0.4459	0.0054	0.4513
9/16	18	0.5665	0.0081	0.5746	0.5264	0.0041	0.5305	0.5024	0.0060	0.5084
⅝	18	0.6290	0.0081	0.6371	0.5889	0.0041	0.5930	0.5649	0.0060	0.5709
¾	16	0.7545	0.0090	0.7635	0.7094	0.0045	0.7139	0.6823	0.0068	0.6891
⅞	14	0.8802	0.0100	0.8902	0.8286	0.0049	0.8335	0.7977	0.0077	0.8054
1	14	1.0052	0.0100	1.0152	0.9536	0.0049	0.9585	0.9227	0.0077	0.9304
1⅛	12	1.1310	0.0116	1.1426	1.0709	0.0056	1.0765	1.0348	0.0090	1.0438
1¼	12	1.2560	0.0116	1.2676	1.1959	0.0056	1.2015	1.1598	0.0090	1.1688
1½	12	1.5060	0.0116	1.5176	1.4453	0.0056	1.4515	1.4098	0.0090	1.4188

[1] Basic diameters.
[2] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root.
[3] The tolerances specified for the pitch diameter are cumulative and include all errors of lead and angle.

TABLE 9—CLASS IIB, MEDIUM FIT, FOR SCREWS OF THE FINE THREAD SERIES

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Minor Diameter		
		Max.[1]	Tolerance	Min.	Max.[1]	Tolerance[3]	Min.	Max.[2]	Tolerance	Min.
0	80	0.0600	0.0026	0.0574	0.0519	0.0013	0.0506	0.0447	0.0022	0.0425
1	72	0.0730	0.0026	0.0704	0.0640	0.0013	0.0627	0.0560	0.0023	0.0537
2	64	0.0860	0.0028	0.0832	0.0759	0.0014	0.0745	0.0668	0.0025	0.0643
3	56	0.0990	0.0030	0.0960	0.0874	0.0015	0.0859	0.0771	0.0028	0.0743
4	48	0.1120	0.0032	0.1088	0.0985	0.0016	0.0969	0.0864	0.0031	0.0833
5	44	0.1250	0.0032	0.1218	0.1102	0.0016	0.1086	0.0971	0.0032	0.0939
6	40	0.1380	0.0034	0.1346	0.1218	0.0017	0.1201	0.1073	0.0035	0.1038
8	36	0.1640	0.0036	0.1604	0.1460	0.0018	0.1442	0.1299	0.0038	0.1261
10	32	0.1900	0.0038	0.1862	0.1697	0.0019	0.1678	0.1517	0.0042	0.1475
12	28	0.2160	0.0044	0.2116	0.1928	0.0022	0.1906	0.1722	0.0048	0.1674
1/4	28	0.2500	0.0044	0.2456	0.2268	0.0022	0.2246	0.2062	0.0048	0.2014
5/16	24	0.3125	0.0048	0.3077	0.2854	0.0024	0.2830	0.2614	0.0054	0.2560
3/8	24	0.3750	0.0048	0.3702	0.3479	0.0024	0.3455	0.3239	0.0054	0.3185
7/16	20	0.4375	0.0052	0.4323	0.4050	0.0026	0.4024	0.3762	0.0063	0.3699
1/2	20	0.5000	0.0052	0.4948	0.4675	0.0026	0.4649	0.4387	0.0063	0.4324
9/16	18	0.5625	0.0060	0.5565	0.5264	0.0030	0.5234	0.4943	0.0070	0.4873
5/8	18	0.6250	0.0060	0.6190	0.5889	0.0030	0.5859	0.5568	0.0070	0.5498
3/4	16	0.7500	0.0064	0.7436	0.7094	0.0032	0.7062	0.6733	0.0077	0.6656
7/8	14	0.8750	0.0072	0.8678	0.8286	0.0036	0.8250	0.7874	0.0088	0.7786
1	14	1.0000	0.0072	0.9928	0.9536	0.0036	0.9500	0.9124	0.0088	0.9036
1 1/8	12	1.1250	0.0080	1.1170	1.0709	0.0040	1.0669	1.0228	0.0101	1.0127
1 1/4	12	1.2500	0.0080	1.2420	1.1959	0.0040	1.1919	1.1478	0.0101	1.1377
1 1/2	12	1.5000	0.0080	1.4920	1.4459	0.0040	1.4419	1.3978	0.0101	1.3877

[1] Basic diameters.
[2] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root.
[3] The tolerances specified for the pitch diameter are cumulative and include all errors of lead and angle.

TABLE 10—CLASS IIB, MEDIUM FIT, FOR NUTS OF THE FINE THREAD SERIES

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Minor Diameter		
		Min.[2]	Tolerance	Max.	Min.[1]	Tolerance[3]	Max.	Min.	Tolerance	Max.
0	80	0.0609	0.0022	0.0631	0.0519	0.0013	0.0532	0.0465	0.0013	0.0478
1	72	0.0740	0.0023	0.0763	0.0640	0.0013	0.0653	0.0580	0.0015	0.0595
2	64	0.0871	0.0026	0.0897	0.0759	0.0014	0.0773	0.0691	0.0017	0.0708
3	56	0.1003	0.0028	0.1031	0.0874	0.0015	0.0889	0.0797	0.0019	0.0816
4	48	0.1135	0.0031	0.1166	0.0985	0.0016	0.1001	0.0894	0.0023	0.0917
5	44	0.1266	0.0033	0.1299	0.1102	0.0016	0.1118	0.1004	0.0025	0.1029
6	40	0.1398	0.0035	0.1433	0.1218	0.0017	0.1235	0.1109	0.0027	0.1136
8	36	0.1660	0.0038	0.1698	0.1460	0.0018	0.1478	0.1339	0.0030	0.1369
10	32	0.1923	0.0041	0.1964	0.1697	0.0019	0.1716	0.1562	0.0034	0.1596
12	28	0.2186	0.0048	0.2234	0.1928	0.0022	0.1950	0.1773	0.0039	0.1812
1/4	28	0.2526	0.0048	0.2574	0.2268	0.0022	0.2290	0.2113	0.0039	0.2152
5/16	24	0.3155	0.0054	0.3209	0.2854	0.0024	0.2878	0.2674	0.0045	0.2719
3/8	24	0.3780	0.0054	0.3834	0.3479	0.0024	0.3503	0.3299	0.0045	0.3344
7/16	20	0.4411	0.0062	0.4473	0.4050	0.0026	0.4076	0.3834	0.0054	0.3888
1/2	20	0.5036	0.0062	0.5098	0.4675	0.0026	0.4701	0.4459	0.0054	0.4513
9/16	18	0.5665	0.0070	0.5735	0.5264	0.0030	0.5294	0.5024	0.0060	0.5084
5/8	18	0.6290	0.0070	0.6360	0.5889	0.0030	0.5919	0.5649	0.0060	0.5709
3/4	16	0.7545	0.0077	0.7622	0.7094	0.0032	0.7126	0.6823	0.0068	0.6891
7/8	14	0.8802	0.0087	0.8889	0.8286	0.0036	0.8322	0.7977	0.0077	0.8054
1	14	1.0052	0.0087	1.0139	0.9536	0.0036	0.9572	0.9227	0.0077	0.9304
1 1/8	12	1.1310	0.0100	1.1410	1.0709	0.0040	1.0749	1.0348	0.0090	1.0438
1 1/4	12	1.2560	0.0100	1.2660	1.1959	0.0040	1.1999	1.1598	0.0090	1.1688
1 1/2	12	1.5060	0.0100	1.5160	1.4459	0.0040	1.4499	1.4098	0.0090	1.4188

[1] Basic diameters.
[2] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root.
[3] The tolerances specified for the pitch diameter are cumulative and include all errors of lead and angle.

pitch diameter of the maximum screw and the minimum nut shall be zero for all pitches and all diameters

(6) Tolerance Values. The tolerances for a screw or nut of a given pitch shall be as specified in Table 2.

Screws, Bolts and Nuts

(Proposed Revision of S. A. E. Standard)

The Society has received inquiries from time to time as to standard practice for measuring lengths of screws and bolts, materials, heat-treatments and machining of the present S.A.E. Standard Screws, Bolts and Nuts shown on page C2 of the S.A.E. Handbook. These inquiries were referred to the Screw Threads Division for the purpose of revising the standard to include such data.

The Screw Threads Division recommends that the explanatory text in the S.A.E. Standard for Screws, Bolts and Nuts, page C2 of the S.A.E. Handbook, be revised and extended to read

The length of the effective thread of screws and bolts shall be: $D \times 1.5 + \frac{1}{4}$ in. As bolts and screws conforming to these specifications are primarily intended for use with nuts, the oval end is not included in the nominal length

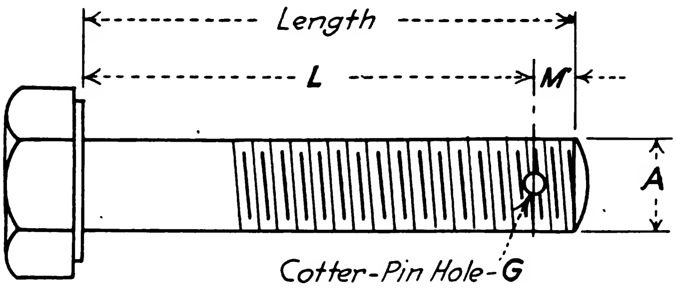
All heads and nuts shall be semi-finished. All screws and nuts shall be made of steel

Unless otherwise specified, S.A.E. Standard screws, bolts and nuts will be made to Class II A (Free Fits) as specified in the (proposed) S.A.E. Standard for Screw-Threads*

S.A.E. Standard bolts without slots or cotter-pin holes are obtainable in stock. If slots, cotter-pin holes or case-hardening are desired, these should be specified by the purchaser

The members of the Division have felt for some time that the present standard would be of more value if it included standard locations of the cotter-pin holes when for use where the latter are used. This subject was referred to Chairman Ehrman, of the Chicago Screw Co., who prepared a report which has been balloted upon favorably by the members of the Division. Therefore

The Screw-Threads Division recommends that the accompanying table indicating cotter-pin locations be added to the present S.A.E. Standard of Screws, Bolts and Nuts, page C2 of the S.A.E. Handbook.



Cotter-pin holes shall be located by dimension *L*

A†	G†	M	A†	G†	M	A†	G†	M
1/4-28	5/64	3/32	9/16-18	5/32	9/64	1 -14	5/32	3/16
5/16-24	5/64	3/32	5/8-18	5/32	5/32	1 1/8-12	7/32	7/32
3/8-24	1/8	7/64	11/16-16	5/32	5/32	1 1/4-12	7/32	7/32
7/16-20	1/8	7/64	3/4-16	5/32	3/16	1 3/8-12	1/4	1/4
1/2-20	5/32	1/8	7/8-16	5/32	3/16	1 1/2-12	1/4	1/4

*This proposed standard is taken from the Progress Report of the National Screw Thread Commission as reviewed by the Working Committee of the Sectional Committee, which is sponsored by the Society and the American Society of Mechanical Engineers.

†S.A.E. Standard, page C2, S.A.E. Handbook.

Gages and Gaging

(Proposed General Information)

The Screw Threads Division has undertaken to prepare articles covering various phases of screw-thread practice and matters germane thereto for publication as general information in The Journal and subsequently in the S.A.E. Handbook.

At the meeting of the Division held on May 1 Earl Buckingham, of Pratt and Whitney Company, who had been delegated to prepare a treatise on the fundamentals of gages and gaging for screw-thread products, submitted a report which was approved by the Division as general information.

The Division recommends that the following statement submitted by Mr. Buckingham be approved by the Standards Committee for publication as general information only.

GAGES AND GAGING FOR SCREW-THREADS

I. Introductory

The art of measuring screw-threads has developed very rapidly during the past few years. This development still continues, so that it would be extremely inadvisable to attempt to specify any one definite method as standard for this purpose. The object of this report is to establish so far as possible the fundamentals of this subject, and to point out various practices now successfully used.

II. Fundamentals

Object of Gaging.—The final result sought by gaging is interchangeable manufacture in some degree. This means that the mating parts can be assembled without *fitting* one part to another and, when assembled, the mechanism will function properly. Gaging should be employed more to prevent unsatisfactory parts from being produced than to sort out the correct parts from the incorrect ones.

Direction of Tolerances on Gages.—The extreme sizes for all limit-gages shall never exceed the extreme limits of the part being produced. All variations in the gages, whatever their cause or purpose, shall bring these gages within these extreme limits. Thus a gage that represents a minimum limit may be larger, but never smaller, than the minimum size specified for the part being produced, while the gage that represents a maximum limit may be smaller, but never larger, than the maximum size specified for the part being produced.

Temperature at Which Gages Shall Be Standard.—Gages shall be standard at a temperature of 68 deg. fahr.

Standard or Basic Size.—The standard or basic size, as physically represented by a correct standard master-gage, is the line at which interference begins between mating parts.

Purpose of "Go" and "Not Go" Gages.—The "Go" gages, which are the gages that represent the maximum limit of the internal member and the minimum limit of the external member, control the allowances between mating surfaces and also control interchangeability. "Go" gages control the maximum tightness in the fit of mating parts. Parts that are acceptable to proper "Go" gages will always interchange. Successful interchangeable manufacturing has been carried on for many years with the use of "Go" gages only.

The "Not Go" gages limit the extent of the permissible variations, thus limiting the amount of looseness between mating parts. "Not Go" gages control the maximum looseness in the fit of mating parts and thus control, in large measure, the proper functioning of the assembled mechanisms.

III. Gage Classification

Master Gage.—The master gage is a plug thread-gage that represents as exactly as possible the physical dimensions of the nominal or basic size of the component. A *standard master-gage* shall be accompanied by a record of its measurement and the gage should be used with knowledge of any deviations or corrections. In case of question, the deviations of this gage from the exact standard shall be ascertained by the Bureau of Standards.

Reference Gage.—A commonly used name for a master gage. Sometimes such gages include those that represent the extreme limits of the product and are used to check the inspection and working gages.

Gages Used to Measure the Product.—The gages used to check the product may be divided into two general types: mechanical and optical. Both types, however, are controlled by the master gages. In general, most of the parts accepted by one method of gaging will be accepted by the other. It should be pointed out, however, that those parts which are close in size to either rejection-point, may be accepted by one system and rejected by the other.

Mechanical gages are often divided into two classes: inspection gages and working gages. Inspection gages are for the use of the inspector in accepting the product. They are generally of the same design as the working gages and the dimensions are such that they represent very nearly the extreme limits of the part being produced. Working gages are those used by the workman to check the parts as they are machined. It is recommended that, when successive inspections are required, the working gages, by either design or selection, be of such dimensions that they are inside the limits of the gages used in succeeding inspections.

When gages of the optical type are employed, the same or duplicate instruments are used for both classes of inspection. No distinction in size is necessary, as the elements of wear and "feel" are not involved in this method of measuring.

IV. Gaging Practices and Gages

The production of accurate parts is primarily a matter of eternal vigilance. The smaller the limits that are to be maintained, the more complete the inspection or gaging system must be. To secure satisfactory results, the manufacturing tools provided must be sufficently accurate and the manufacturing methods sufficiently reliable to produce the required results. After tools and methods of proved reliability are provided, the next point is to watch the wear on the tools or their set-up to assure the maintenance of the required conditions. This is accomplished sometimes by a periodical test of the tools, sometimes by periodical gaging of the product, and sometimes by both.

Thread Micrometers.—Thread micrometers are used extensively to measure the pitch-diameter of taps and threaded internal parts. Thread micrometers should be calibrated periodically against a master gage, to avoid errors due to wear on the anvils of the instrument. Thread micrometers give no indication of lead and angle errors; therefore, the results of tests with thread micrometers alone cannot be taken as conclusive.

Thread Snap-Gages.—Thread snap-gages, generally consisting of conical points, are commonly used to measure the pitch-diameter of screws and other threaded internal parts. As in the case of thread micrometers, these gages give no indication of lead and angle errors. Therefore, the results of tests with them alone cannot be taken as conclusive.

Ring Thread-Gages.—Ring thread-gages are used extensively to measure the thread on internal parts. These are usually adjustable and are adjusted to suitable master or reference gages. Where parts are to be produced within specified limits, "Go" and "Not Go" gages are required. The thread on the "Go" gage is made of full form with its major diameter cleared or undercut to give a suitable clearance for grinding or lapping. The "Not Go" gage should be made primarily to check the minimum pitch-diameter. The minor diameter of such a gage should therefore never be smaller than the minor diameter of its corresponding "Go" gage, and its major diameter should be cleared as in the case of the "Go" gage. The use of such gages gives a certain measure of lead and angle errors, as well as of pitch-diameter errors. A proper "Go" gage will reject any parts that exceed the maximum dimensions specified. The "Not Go" gage, however, does not necessarily reject all parts that exceed the specified cumulative tolerance. It is possible, with the use of such gages, to accept parts that exceed this cumulative tolerance because of lead or angle errors, or both. With the proper check on tools and manufacturing methods, however, such possibilities are the exception. Such gages have been used successfully for many years.

Thread Comparators.—A recent development in the art of measuring threaded parts is the thread comparator, usually an optical instrument. These optical instruments throw an enlarged image of the thread upon a screen where it is compared with the enlarged outline of the required form. The location of the form used for comparison is made to agree with the image of the master gage. With such instruments all errors, both individual and cumulative, of diameter, lead and angle can be determined readily. These instruments can be adapted to measure taps and threaded internal parts.

Plug Thread-Gages.—Plug thread-gages are used exclusively at the present time to measure threaded holes or threaded external parts. Where parts are to be produced within specified limits, "Go" and "Not Go" gages are required. The thread on the "Go" gage is made of full form with its minor diameter cleared or undercut to give a suitable clearance for grinding or lapping. The "Not Go" gage should be made primarily to check the maximum pitch-diameter. The major diameter of such a gage should therefore never be larger than the major diameter of its corresponding "Go" gage, and its minor diameter should be cleared as in the case of the "Go" gage. The use of such gages gives a certain measure of lead and angle errors, as well as of pitch-diameter errors. A proper "Go" gage will reject any parts that exceed the minimum dimensions specified. The "Not Go" gage, however, as in the case of the ring thread-gage, does not necessarily reject all parts that exceed the specified cumulative tolerance.

Methods of Inspecting Screws.—One practice of inspecting screws produced on automatic machines is to provide a ring thread-gage set to approximately the mean size between the maximum and minimum limits. The threading tools are then set so that the product enters this intermediate gage, but will not enter the minimum or "Not Go" gage. The machine is then started up and parts are tested periodically with the regular "Go" gage and the intermediate gage. When the parts have increased in size so that they will not enter the intermediate gage more than three or four turns, the set-up is changed, even though the parts are still acceptable to the "Go" gage.

A very similar plan can be followed when a screw-thread comparator is employed. The original set-up should be toward the minimum limit and the set-up should be changed as the maximum limit is approached.

Reference has been made to successive inspections. Although the manufacturer may give but one inspection, it should be realized that the purchaser often inspects the product to assure that the prescribed specifications have been fulfilled. Therefore, to reduce the possibilities of disagreement to a minimum, the manufacturer should strive to produce parts well within the specified limits rather than close to the limiting sizes.

Thread micrometers and thread snap-gages are used extensively for testing the product as it is produced. As these instruments do not test all elements of the screw-thread, a "Go" gage should always be used as a supplementary test. Thread micrometers are a very effective means of watching the change in set-up due to wear on tools, etc.

Methods of Inspecting Tapped Holes.—One practice of inspecting tapped holes is first to inspect the tap, and then test the tapped holes periodically with suitable gages. The tap can be watched for wear by testing the tapped holes with a "Go" thread-gage. One widely used practice consists of using a "Go" plug thread-gage and a "Not Go" plain plug-gage for the minor diameter.

Another practice of inspecting taps is to measure the several elements, such as pitch-diameter, angle and lead; and still another consists of tapping a hole with each tap before it is issued from the tool-crib and testing these tapped holes with "Go" and "Not Go" plug thread-gages.

V. Inspection of Gages

When successive inspections in the same plant are involved, it is good practice to inspect all gages of the same nominal

size against each other periodically, and to distribute these gages so that the earlier inspections will be made with those that are the greatest amount inside of the component tolerance, and the later inspections with those gages closest in size to the component tolerance.

PASSENGER-CAR BODY DIVISION REPORT

Division Personnel

G. E. Goddard, *Chairman*	Dodge Bros.
A. J. Neerken, *Vice-Chairman*	Hupp Motor Car Corporation
Wm. Brewster	Brewster & Co.
E. G. Budd	Edward G. Budd Mfg. Co.
J. S. Burdick	Buffalo Body Corporation
O. H. Clark	Zeder-Skelton-Breer Engineering Co.
A. E. Garrels	Studebaker Corporation of America
E. W. Goodwin	Body Expert
G. W. Kerr	Rolls-Royce of America, Inc.
G. J. Mercer	Consulting Engineer
H. C. Nelson	Mullins Body Corporation

Top-Irons

(Proposed S.A.E. Recommended Practice)

One of the first subjects considered by the Passenger-Car Body Division was the standardization of top-irons. Information on present practice was obtained which indicated that a threaded-end with 7/16-14 U. S. Standard threads is used generally. Consideration was given to the possibility of standardizing a series of complete top-irons, and O. H. Clark, formerly with the Willys Corporation, was appointed a Subdivision to study the matter. A tentative recommendation was submitted which was printed in The Journal. Further consideration of the subject, however, indicated that only the threaded end of the top-iron should be standardized, as the other dimensions depends largely on individual conditions that do not lend themselves readily to interchangeability of top-irons. Therefore

The Division recommends for S.A.E. Recommended Practice that the threaded-end of top-irons shall be 7/16-14 U. S. Standard thread

SPRINGS DIVISION REPORT

Division Personnel

S. P. Hess, *Chairman*	Detroit Steel Products Co.
H. R. McMahon, *Vice-Chairman*	Standard Steel Spring Co.
R. S. Begg	Jordan Motor Car Co.
E. S. Corcoran	Kelly-Springfield Motor Truck Co.
H. E. Figgie	Perfection Spring Co.
W. M. Newkirk	William & Harvey Rowland, Inc.
Gustof Peterson	Electric Alloy Steel Co.
E. V. Rippingille	Watson Stabilator Co.
F. A. Whitten	General Motors Truck Co.

Spring-Eye Bushings

(Proposed Revision of S.A.E. Recommended Practice)

The Springs Division has reviewed the existing spring standards and believes that the present S.A.E. Recommended Practice for Spring-Eye Bushings and Bolt Tolerances, page H5 of the S.A.E. Handbook, should specify the tolerances for the spring-eye bushings only, the allowable bolt tolerances being properly a matter for the bolt manufacturers to decide. Therefore

The Springs Division recommends that the present S.A.E. Recommended Practice for Spring-Eye Bushing and Bolt Tolerances be revised by the elimination of the bolt tolerances, the title of the Recommended Practice to be changed to "Spring-Eye Bushings."

Definitions

(Proposed S.A.E. Standard)

The Springs Division, in reviewing the existing Spring standards, has felt that definitions of terms used in the spring industry would be of material value in preventing many misunderstandings due to different interpretations of such terms. A Subdivision has been at work redrafting "Leaf-Spring Specifications" and in connection with this work the members of the Division have prepared the following definitions which are recommended for adoption by the Society.

This report probably should be adopted at this time as a section of the present S.A.E. Standard for Leaf-Spring Nomenclature, page H1 of the S.A.E. Handbook. However, in the further development of standardization of automotive springs, it may be desirable to make these definitions a part of some other section of the standards, or an individual standard. This can be arranged for after the adoption of the definitions by the Society, as the work of the Division progresses.

The Springs Division recommends the adoption of the following definitions as S.A.E. Standard:

DEFINITIONS

Deflection.—The amount of travel of a spring under the application of a specified load, expressed as inches per pound.

Flexibility.—The flexing characteristics of a spring, determined by the weight which will deflect it 1 in., expressed as pounds per inch. (See "Flexibility Test," page H19, S.A.E. Handbook.)

Composite Springs.—Springs made of leaves (or plates), one or more of which are of alloy steel and the rest of carbon steel.

Unsprung Weight.—The total weight of all parts not supported on the springs, including axles, wheels, rims and tires complete.

Rated Load.—The load which the vehicle manufacturer specifies shall be carried by the springs at a given spring-height.

Load Clearance.—The maximum distance through which a spring can travel beyond its rated load position, before striking.

Load Height.—The distance from a line through the center of the spring-eyes to the face of the axle-pad, when the spring is deflected to rated load.

Load Length.—The distance between the centers of the spring-eyes when the spring is deflected to rated load.

Free Height.—The distance from a line through the center of the spring-eyes to the face of the axle-pad, when the spring is in a free, unloaded position.

Frame Brackets for Springs

(Proposed Cancellation of S.A.E. Recommended Practice)

In reviewing the present S.A.E. Recommended Practice for Frame Brackets for Springs, page H6 of the S.A.E. Handbook, the Springs Division found that it is neither complete nor in accord with present practice. It is thought that the standard is of little value because each car builder has varying conditions to meet and determines its practice accordingly. Therefore

The Springs Division recommends that the present S.A.E. Recommended Practice for Frame Brackets for Springs, page H6 of the S.A.E. Handbook, be cancelled.

LUBRICANTS DIVISION REPORT

Division Personnel

H. C. Mougey, *Chairman*	General Motors Research Corporation
W. E. Jominy, *Vice-Chairman*	Studebaker Corporation
Sydney Bevin	Tide Water Oil Co.
P. J. Dasey	Midwest Engine Co.
A. P. Eves	International Harvester Co.
W. H. Herschel	Bureau of Standards
K. G. Mackenzie	Texas Co.
W. E. Perdew	Union Petroleum Co.
H. G. Smith	Atlantic Refining Co.
J. W. Stack	Standard Oil Co.

CRANKCASE LUBRICATING OIL

(*Progress Report Only*)

One of the most important subjects before the Standards Committee is the establishing of definite specifications for different grades of engine crankcase oil used by the several groups of the automotive industry. The Lubricants Division was reorganized on an active basis in 1921 and work started on formulating practical specifications for crankcase oils, cup greases, transmission greases and other classes of lubricant. The work of the Federal Government, conducted by the Bureau of Mines in the Interdepartmental Committee on the Standardization of Petroleum Specifications, and the standard methods of testing adopted by the American Society for Testing Materials, have been considered carefully by the Division.

In November 1921 a questionnaire was sent to passenger-car, motor-truck, tractor, motorcycle, motorboat, transmission and lubricant manufacturers, together with the Division's tentative specifications for crankcase oils, except for airplanes; motorcycle oils and transmission oils, requesting information as to changes or additions which should be made.

After a preliminary discussion of the tentative specifications at meetings of some of the Divisions representing automotive groups, a joint meeting of the Lubricants Division and members of the Agricultural Power Equipment, the Truck, the Passenger-Car, the Stationary-Engine, the Isolated Electric-Lighting Plant and the Engine Divisions and representatives of large oil producing companies was held in April.

The specifications were discussed thoroughly and revised somewhat in substance, heavier grades being added to the list and the separate specifications for automobile and motorcycle oils combined. The preparation of specifications for transmission lubricants has been referred to a Subdivision consisting of W. E. Jominy, of the Studebaker Corporation of America, and H. G. Smith, of the Atlantic Refining Co.

The Division is presenting the revised tentative proposal at this time as a progress report only, for the purpose of securing discussion from Standards Committee members and guests. It is hoped that this discussion will develop information and suggestions that will be of value to the Division in its work, so that, when the specifications are finally recommended for adoption by the Society, the Division may be assured that the specifications are approved generally and conform with the best lubricating-oil practice.

General.—These specifications cover grades of petroleum oil for the lubrication of internal-combustion engines, except aircraft, and are not recommended for the lubrication of turbines.

Only refined petroleum oils without admixture of fatty oils, resins, soaps or other compounds not derived from crude petroleum will be considered.

Corrosion Test.—The following corrosion test shall not cause discoloration of copper strip. Place a clean piece of mechanically polished pure strip copper about ½ in. wide and 3 in. long, and 10 cc. of the oil to be tested, in a clean test-tube. Close the tube with a vented stopper and hold for 3 hr. at 210 deg. fahr. Rinse the copper strip with sulphur-free acetone and compare it with a similar strip of freshly polished copper

Precipitation Number.—The precipitation number shall not be greater than 0.5 when determined by the method described in the American Society for Testing Materials Tentative Standard Method of Test for Pre-

ENGINE CRANKCASE OILS

Tentative specifications, April 18, 1922

General.—These specifications cover grades of petroleum oil for the lubrication of internal-combustion engines, except aircraft, and are not recommended for the lubrication of turbines.

Only refined petroleum oils without admixture of fatty oils, resins, soaps or other compounds not derived from crude petroleum will be considered.

Specification No.*	Flash-Point, Min.	Fire-Point, Min.	Viscosity Saybolt Sec. 100 Deg. Fahr. Min.	Viscosity Saybolt Sec. 100 Deg. Fahr. Max.	Viscosity Saybolt Sec. 210 Deg. Fahr. Min.	Viscosity Saybolt Sec. 210 Deg. Fahr. Max.	Color (NPA) Darkest color allowed on mixture of oil and 50 per cent kerosene	Pour Test, Max.	Acidity, Mg. KOH per Gram., Max.	Conradson Carbon Residue, Per Cent, Max.	Precipitation Number
20	325	365	180	220	43	....	5	35	0.15	0.20	....
020	325	365	180	220	43	....	5	0	0.15	0.20	....
30	335	380	270	330	46	....	5	40	0.15	0.30	....
030	335	380	270	330	46	....	5	0	0.15	0.30	....
40	345	390	360	440	49	....	5	45	0.15	0.40	....
50	355	400	450	550	52	....	6	50	0.15	0.60	....
60	360	.....	.....	.....	55	65	....	55	0.15	0.80	....
80†	400†	.....	.....	.....	75	85	....	15	0.15	1.5	0.5
95	400	.....	.....	.....	90	100	....	45	0.15	1.5	0.5

A corrosion test is required for all grades.

*For Specifications Nos. 20 to 50 inclusive, the numbers indicate the first two figures of the average Saybolt viscosity in seconds at 100 deg. fahr. of the grades indicated. The cipher preceding Specifications Nos. 20 and 30 indicate that the pour-test value of these two grades is zero. Nos. 60, 80 and 95 indicate the average Saybolt viscosity in seconds for these three grades at 210 deg. fahr.

†The limits for No. 80 are to be reviewed by the Lubricants Division, as it is felt that the pour-test limit for this grade of oil is low.

cipitation Number of Lubricating Oils, No. D91-21T. The precipitation number is the number of cubic centimeters of precipitate formed when 10 cc. of lubricating oil is mixed with 90 cc. of petroleum naphtha of definite quality and centrifuged under definite prescribed conditions

OBITUARIES

FRANK W. EDWARDS, sales engineer of the Dayton Engineering Laboratories Co., died April 29 at his residence in Dayton, Ohio, aged 41 years. His death was due to an acute case of pneumonia. He was born at Georgetown, Ohio, April 10, 1881, and received his education in the high school and the night school of the Y. M. C. A.

In 1901 Mr. Edwards entered the service of the Central Union Telephone Co., as a stock keeper and before leaving in July, 1905, had been promoted to assistant wire chief. From the Central Union Telephone Co. he went to the National Cash Register Co. at Dayton, remaining there 7 years. He was first connected with the electrical department and after serving there for a while was later engaged in installing electrical systems in the department stores of that city. On Aug. 1, 1912, he became associated with the Dayton Engineering Laboratories Co., serving in its experimental laboratory for 6 months and then having charge of the installing of experimental starting, lighting and ignition systems at automobile factories for 2 years. From 1914 until the time of his death Mr. Edwards served in the sales department with the title of sales engineer.

Mr. Edwards was elected to Associate Member grade in the Society Sept. 8, 1915, and was transferred to Member grade June 16, 1918.

HENRY HESS, one of the founder members of the Society and president in 1909, died on March 23, 1922, at his home in Atlantic City, N. J. At the time of his death Mr. Hess was president and chief engineer of the Hess Steel Corporation which he organized in 1912.

Henry Hess was born in Darmstädt, Germany, in March, 1864. He received his early education in private schools at New York City, later studying in Germany. His practical experience was obtained in the machine shop, drawing room and office, in turn as machinist, foreman, draftsman and manager, chiefly with machine-tool builders and the United States Government. While in the service of the Niles Tool Works, he designed its German plant and was sent to Oberschoeneweide near Berlin where he had charge of its erection, remaining there several years as director and consulting engineer. On his return to the United States in 1902 he organized the Hess-Bright Mfg. Co. for the manufacture and sale of ball bearings conforming to the German D. W. and M. design. He sold his interests in this company in 1912, when he organized the Hess Steel Corporation of Baltimore, serving as president and chief engineer of this company until his death.

Mr. Hess was very active in the early standardization work of the Society that has become of such importance to the industry at large. He was chairman of the Gear-Tooth Shapes and the Technical Index Divisions from 1911 to 1914 and a member of the Ball and Roller Bearings Division from 1910 to 1913. He was also chairman of the Pennsylvania Section of the Society from 1911 to 1913. He was a member of the American Society of Mechanical Engineers, serving as manager from 1911 to 1914 and as vice-president from 1914 to 1916. He was also a past-president of the Philadelphia Engineers' Club, a member of the American Institute of Mining Engineers, the American Society for Testing Materials, the American Iron and Steel Institute, the American Electrochemical Society, the American Academy of Political and Social Science, the Franklin Institute, the New York Engineers' Club, the Art Club and the Economics Club.

Mr. Hess is survived by his widow, two daughters and a son, H. Lawrence Hess, a member of the Society.

TEST APPARATUS FOR PROPELLER MODELS

SPECIAL apparatus of interesting design has been devised by S. Albert Reed, New York City, for the testing of high-speed propeller models. In this apparatus an electric motor is employed to drive the propeller-shaft through a set of gears that increases the motor speed four times. This gear is balanced, that is, mounted on two countershafts, an arrangement which is designed to relieve the shaft of all strains except that of torsion inasmuch as the shaft is floating. Instead of providing for thrust play by a sliding joint in the shaft, the entire propeller-shaft with its pinion slides to and fro between the countershaft gears, thus doing away with any binding due to the fact that the gear teeth mesh and disengage at a high rate of speed.

The longitudinal play of the propeller-shaft was approximately ½ in. and the shaft has a collar with a ball-bearing against it that is carried by hinged lever, the free end of which is held back by a spring scale for measuring the thrust. The thrust bearing presented some novel problems inasmuch as a maximum thrust of 500 lb. at 6000 r.p.m. must be provided for, which is considerably in excess of the usual range of ball-bearing practice. This problem was solved by the use of tandem ball-bearings, in which the speed of each was reduced in the ratio of the number in tandem. To measure the torque the stress on the countershafts transmitting the motion from the motor shaft to the propeller-shaft was utilized by an extension of the principle of the well-known transmission dynamometer. The torque of the frame or box carrying the countershafts has a certain fixed ratio to the speed and horsepower being transmitted at any minute and this value was transmitted by an arm to a spring scale that gave accurate measurements.

FACILITY OF ASSOCIATION

THE spirit of suspicion, selfishness, intolerance and controversy complicates all our problems, domestic and international. Racial prejudices, together with narrow and mistaken views of national interests, are responsible for wars. We wonder at industrial disputes, in which questions of immediate personal interest are involved and where the participants are often lacking in education and breadth of culture.

The truth is that it is very hard for people to get along together without friction and antagonism. Emerson said that "facility of association" is the measure of civilization, meaning that as people become enlightened and broad-minded they develop the ability to cooperate in higher and higher degree. The ability to work together harmoniously and effectively for common interests and purposes is the measure of civilization and the general condition of social progress.

The gains of society in the last 100 years have been accomplished for the most part by improvements in the methods of production, by the use of power and machinery. They have been accomplished by the development of the industrial plant, and the industrial plant represents the earnings and savings and profits of individuals. If the profits had been less, the industrial development would have been less, and the evils of scarcity and high prices would have been greater than they are.

In the 10 years from 1899 to 1909, population in the United States increased 21 per cent, while the amount of capital invested in the manufacturing industries increased 105 per cent, and the amount of power employed in these industries increased 85 per cent.—George E. Roberts.

ACTIVITIES OF THE SECTIONS

Secretaries of the Sections

BUFFALO SECTION—A. J. Fitzgibbons, 168 Claremont Avenue, Buffalo
CLEVELAND SECTION—E. W. Weaver, 5103 Euclid Avenue, Cleveland
DAYTON SECTION—R. B. May, Dayton Engineering Laboratories, Dayton
DETROIT SECTION—Thomas J. Litle, Jr., 733 Seyburn Avenue, Detroit
Mrs. B. Brede, Assistant Secretary, 1361 Book Building, Detroit
INDIANA SECTION—B. F. Kelly, Weidely Motors Co., Indianapolis
METROPOLITAN SECTION—R. E. Plimpton, 129 East 45th Street, New York City
MID-WEST SECTION—H. O. K. Meister, Hyatt Roller Bearing Co., 2715 South Michigan Avenue, Chicago
MINNEAPOLIS SECTION—Phil N. Overman, 10 South 10th Street, Minneapolis
NEW ENGLAND SECTION—V. A. Nielsen, 701 Beacon Street, Boston.
PENNSYLVANIA SECTION—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
WASHINGTON SECTION—Benjamin R. Newcomb, 211 Victor Building, City of Washington

THE Sections of the Society closed the spring season of activitiy with their May meetings in most cases. One or two of the Sections are planning summer outings of a social nature but in general they will hold no meetings until the fall. The new Section officers took up the reins during the month and will be responsible for the programs arranged for the next Section year. The interest in Section meetings this past winter has been gratifying, but it is the ambition of the Council and the Sections Committee to encourage even greater activity during the coming year. With this in mind, a special Sections luncheon will be a feature of the White Sulphur Springs Meeting. Representatives of all of the Sections will meet with the Councilors and the Sections Committee to discuss ways and means of attaining maximum interest in Section meetings and planning them to render the greatest service to the industry on engineering problems that are urgent. Several of the members who have been especially active and successful in the administration of Sections affairs will address the luncheon and relate their experiences for the benefit of the new Section officers.

New Section Officers

The result of the election of new officers was announced by all of the Sections at their May meetings except in the case of the Pennsylvania Section. Study of the following list convinces one that considerable care was taken by the respective nominating committees in the making of selections, and forecasts an active year among the Section members.

BUFFALO SECTION

E. O. Spillman	Chairman
C. A. Criqui	Vice-Chairman
Otto M. Burkhardt	Treasurer
A. J. Fitzgibbins	Secretary

CLEVELAND SECTION

O. A. Parker	Chairman
R. J. Nightingale	Vice-Chairman
H. E. Figgie	Treasurer
E. W. Weaver	Secretary

DAYTON SECTION

J. H. Hunt	Chairman
Iskander Hourwich	Vice-Chairman
Robert F. McCann	Treasurer
R. B. May	Secretary

DETROIT SECTION

George E. Goddard	Chairman
K. K. Hoagg	Vice-Chairman
Charles S. Whitney	Treasurer
Thomas J. Litle, Jr.	Secretary

INDIANA SECTION

O. C. Berry	Chairman
Lon R. Smith	Vice-Chairman
Mark A. Smith	Treasurer
B. F. Kelly	Secretary

METROPOLITAN SECTION

W. E. Kemp	Chairman
H. W. Slauson	Vice-Chairman
W. P. Kennedy	Treasurer
R. E. Plimpton	Secretary

MID-WEST SECTION

Taliaferro Milton	Chairman
Benjamin S. Pfeiffer	Vice-Chairman
Nelson B. Nelson	Treasurer
H. O. K. Meister	Secretary

MINNEAPOLIS SECTION

A. H. Bates	Chairman
Victor Gauvreau	Vice-Chairman
J. S. Clapper	Treasurer
Phil Overman	Secretary

NEW ENGLAND SECTION

H. E. Morton	Chairman
H. F. Peavey	Vice-Chairman
L. B. F. Raycroft	Treasurer
V. A. Nielsen	Secretary

WASHINGTON SECTION

Col. F. H. Pope	Chairman
Chester H. Warrington	Vice-Chairman
Conrad H. Young	Treasurer
Benj. H. Newcomb	Secretary

Inter-Section Athletics

One of the features of the sports program at the White Sulphur Springs Meeting will be the athletic struggle to determine which Section will be the Sports Champion of 1922. At Summer Meetings of the past, only two or three Inter-Section events have been arranged. The plan this year calls for the crediting of points to the Section represented by the winners, seconds and thirds in all of the numerous events. At the conclusion of the sports program an appropriate cup will be awarded to the Section that boasts the greatest total of points. The battle for supremacy and the good-natured rivalry between Sections will create an atmosphere not unlike that of the inter-collegiate athletic meets of our younger days. The baseball cup emblematic of the Section Championship will be contested between Section teams; Section running and swimming relay races are scheduled; and even the points scored by the ladies will be officially

recognized in the totals. Reports reaching the Society offices tell of committees that are busily organizing ball clubs and influencing golf, tennis and sprint stars to present themselves for action at White Sulphur Springs.

Section Stunts

A Summer Meeting would not be complete without the famous Section Stunts. Some of the brightest moments of the entertainment are to be provided by the near-actors, virtuosos or circus ringmasters who represent one of the local organizations of the Society. Surprises are being prepared for the June meeting and, of course, a dense cloud of secrecy has been thrown about the plans. The Mid-West Booster, official organ of the Chicago lads, carries in part the following for May, which we cannot refrain from reprinting.

Here are some ideas:

(1) That all of us go to White Sulphur without shoes or socks. Have all the rest of the clothes and be regular in every way; except go barefoot. This would attract some attention

(2) That all of us who go, whenever we are in the presence of people not members of the Mid-West Section, act like deaf-and-dummies and pretend only to be able to talk with our hands. This will save us lots of useless conversation with Eastern reubens. We can learn the finger language on the way down, which will leave us no time for ruinous games of chance

(3) That all of us grow a full beard and mustaches and every fellow call every other fellow in our party "Doc" and we will all wear green spectacles. These whiskers will give us some publicity and will add great dignity to our Section in the eyes of the Bostonese

(4) That every single one of us equip himself with working drawings and talking specifications of some great invention, only they won't be great inventions, only we will all pretend to believe in every one of them and talk publicly and privately about them every chance we get. One fellow can have a scheme for a rain-water substitute for gasoline; another can have a seven-cylinder engine, the extra cylinder being turned on when climbing a hill; another can have a rubber substitute made from the refuse of Italy's macaroni factories, and so on

If this is an indication of what may be expected from the Windy City, the other Sections will surely be put to shame.

Section Pullmans

The Cleveland, Detroit, Mid-West, Metropolitan and Pennsylvania Sections have all arranged to have special Pullman cars transport their members to the Summer Meeting. The Dayton Section members can be accommodated on either the Detroit or Cleveland cars. The Indiana members can make reservations through the Mid-West Section on their cars. The New England and the Washington Sections members can make reservations on the Eastern special train with the Metropolitan and the Pennsylvania Sections. The Section Secretaries have complete information on all of these special Pullmans. Consult the one nearest you and travel to White Sulphur Springs with your friends in the Society.

Mid-West Section

The new officers of the Mid-West Section devoted the meeting on May 12 to a social gathering for the purpose of discussing plans for the fall. Chairman Milton expressed a desire to schedule papers having the greatest general interest. Many good suggestions were offered.

Metropolitan Section

The Metropolitan Section's trip to New Haven via railway motor-cars on the occasion of its April Meeting aroused a surprising amount of interest. As a consequence, the Section officers decided to make Motor Cars on Rails the subject of discussion at the meeting on May 25. The meeting was opened with papers on motor rail-cars by Roy V. Wright and W. L. Bean. Following these, there was an active discussion of the engineering problems involved in the design, construction and operation of this type of automotive vehicles. The meeting was preceded by a well attended dinner.

Minneapolis Section

The Minneapolis Section held an informal meeting of a social character on the evening of May 3 at the Manufacturers Club. The annual reports of officers and committees were read and officers elected for the next Section year. L. A. Emerson was selected to represent the Section on the Society Nominating Committee at White Sulphur Springs.

Pennsylvania Section

The members of the Pennsylvania Section held a very enjoyable outing at the Torresdale Golf Club on May 26. Several heated golf and tennis contests were staged, the ladies being present to enjoy the fun. A palatable dinner was served after the athletic diversions in the afternoon.

Indiana Section

President Bachman and several members of the Council were guests of the Indiana Section at its dinner and social meeting on May 8. Mark A. Smith was elected representative on the Society Nominating Committee and W. G. Wall was selected as alternate. Short talks were given by President Bachman, Past-President Beecroft and others.

Washington Section

The Washington Section held a meeting on the evening of May 5 in the lecture hall of the Cosmos Club. Dr. Harvey Wiley was the speaker and chose as his topic the Metric System and its Practical Use. In view of present agitation in some circles to have the metric units declared by the Congress the national standard, Dr. Wiley's talk resulted in an active general discussion in which he was called upon to answer numerous questions. A buffet supper was provided for the members after the meeting adjourned.

Cleveland Section

Dr. H. C. Dickinson addressed the Cleveland Section members at their meeting on May 19, having as a topic the work being done by the Research Department of the Society. He explained some of the advantages of cooperative research on specific problems and indicated the scope of the Society's activity in this field. William T. Burns presented a paper on power losses in bearings which included valuable tabulated data. The meeting was held in the Hotel Winton and was preceded by an informal dinner.

New England Section

In addition to the election of Section officers, the New England Section elected its representatives on the Society Nominating Committee at the meeting on May 11. L. W. Rosenthal was selected as member and Prof. E. P. Warner was chosen as alternate. After enjoying an informal dinner, the Section heard an extremely interesting paper on the Making of Automobile Tires which was presented by W. W. Duncan. Mr. Duncan illustrated his paper with slides and gave a very clear description of the successive operations followed in building a pneumatic tire.

Detroit Section

The Detroit Section devoted its meeting on May 19 to papers on related subjects, Methods of Producing Cylinder-Wall Surfaces, and Light-Weight Pistons. A. J. Baker discussed present-day methods of machining cylinder-bores and H. B. Carlson made remarks on cylinder lapping. John A. Gann read a paper on light-weight pistons cast from special alloys, and E. Planche presented the results of tests he had made with cars whose engines were equipped with alloy pistons of this type. The meeting was very well attended and was preceded by a buffet supper.

Applicants *for* Membership

The applications for membership received between April 15 and May 15, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, KENNETH B., student, California Institute of Technology, *Pasadena, Cal.*

ATANGAN, TOMAS T., 3800 Grand Boulevard, *Chicago.*

BARNES, ORRIN HAYWARD, student, California Institute of Technology, *Pasadena, Cal.*

BEEGLE, F. N., president, Union Drawn Steel Co., *Beaver Falls, Pa.*

BELL, STANLEY A., student, California Institute of Technology, *Pasadena, Cal.*

BIDDLE, CHARLES JONATHAN, student, California Institute of Technology, *Pasadena, Cal.*

BLAKELY, LOREN E., student, California Institute of Technology, *Pasadena, Cal.*

BOWER, BYRON F., student, Ohio State University, *Columbus, Ohio.*

BRAINERD, HOWARD S., metallurgist, Ingersoll-Rand Co., *Phillipsburg, N. J.*

BRAMLEY, N. F., president and general manager, Templar Motors Co., *Cleveland.*

BREAKEY, EDWIN T., factory superintendent, Columbia Carbureter Co., *Chicago.*

BRICE, JOHN R., layout draftsman, Yellow Cab Mfg. Co., *Chicago.*

BROSSEAU, A. J., president, Mack Trucks, Inc., 25 Broadway, *New York City.*

BRUNNER, ALEXANDER, proprietor, A. Brunner & Son, *Newark, N. J.*

BUELL, ROY D., president, Buell Mfg. Co., *Chicago.*

COWAN, WILLIAM ARTHUR, assistant chief chemist, National Lead Co., *New York City.*

CREAMER, CHARLES DELL, student, Ohio State University, *Columbus, Ohio.*

DE BARRIN, HENRY, engineer designer, Sociedad Automoviles Argus S. A., *Madrid, Spain.*

DE MELTO, VINCENT MARION, student, Ohio State University, *Columbus, Ohio.*

DEMORY, A. R., president, Timken-Detroit Axle Co., *Detroit.*

DICK, JAMES B., production engineer, D'Arcy Spring Co., *Kalamazoo, Mich.*

DOTY, E. M., mechanical engineer, Denby Motor Truck Co., *Detroit.*

DROPINSKI, ADOLPH, student, Armour Institute of Technology, *Chicago.*

DRYER, JAMES C., vice-president, James Cunningham Son & Co., *Rochester, N. Y.*

DUPONT, V. H. MEYER, founder, publisher and sole owner, *Oriental Motor, Shanghai, China.*

EDMUNDS, GEORGE E., president, Edmunds & Jones Corporation, *Detroit.*

FETHERSTON, W. L., manager of trade division, Robert Bosch Magneto Co., *New York City.*

FITZGERALD, EDWARD WILLIAM, inspector of tanks and tractors, Ordnance Department, *Camp Meade, Md.*

FLOYD, ROBERT K., general manager, F. H. Floyd, *Detroit.*

FOGELSON, EMIL, mechanical engineer, Victor Pagé Motors Corporation, *New York City.*

FUHRER, MAX, student, Armour Institute of Technology, *Chicago.*

GIBSON, ALFRED R., 210 Walnut Street, *Montclair, N. J.*

GOLDSTEIN, ALEXANDER, student, Armour Institute of Technology, *Chicago.*

GOMMEL, D. E., chief engineer, Monroe Automobile Co., *Indianapolis.*

GRANNING, M. L., instructor, Oregon Agricultural College, *Corvallis, Ore.*

GRIFFITH, EDWARD W., factory representative, Forsyth Bros. Co., *Harvey, Ill.*

HATCH, DORRILL K., technical sales, Gurney Ball Bearing Co., *Jamestown, N. Y.*

HERBERT, W. H., general sales manager, Denby Motor Truck Co., *Detroit.*

HERRLIN, KARL O., student, Lewis Institute, *Chicago.*

HIGHAM, WILLIAM HARRY MARCUS, senior draftsman, Durant Motors, Inc., *Long Island City, N. Y.*

HOFFMAN, ROBERT J., works manager, Prest-O-Lite Co., Inc., *New York City.*

HOHNKE, JOHN H., student, Michigan Agricultural College, *East Lansing, Mich.*

HOLDER, H. A., president, R. & V. Motor Co., *East Moline, Ill.*

HOSLEY, LORING F., chief engineer, Kelly-Springfield Motor Truck Co., *Springfield, Ohio.*

HOUSE, BRYAN, designer, Maxwell Motor Co., Inc., *Detroit.*

HUEBOTTER, H. A., research assistant, Purdue University, *Lafayette, Ind.*

HULT, ALBERT E., assistant general manager, Detroit Motorbus Co., *Detroit.*

KNERR, HORACE C., metallurgist, Navy Yard, *Philadelphia.*

KNIGHT, RALPH B., superintendent of inspection, North East Electric Co., *Rochester, N. Y.*

KOHR, ROLAND MEREDITH, student, Ohio State University, *Columbus, Ohio.*

KRYZ, EMIL W., mechanical draftsman, Rock Island Arsenal, *Rock Island, Ill.*

LAWSON, CARL, inspector, J. M. Horton Ice Cream Co., *New York City.*

MCDONNELL, EDWARD O., vice-president and general manager, Kelly-Springfield Motor Truck Co., *Springfield, Ohio.*

MACDUFF, D. M., chief engineer, A. J. Detlaff Co., *Detroit.*

MAGDSICK, H. H., engineering department, National Lamp Works of General Electric Co., *Nela Park, Cleveland.*

MARSH, HALLAN N., student, California Institute of Technology, *Pasadena, Cal.*

MARSTON, R. E., executive engineer, Selden Truck Corporation, *Rochester, N. Y.*

MEADER, GLENN S., student, University of Minnesota, *Minneapolis.*

MIKI, KICHIHEI, Frazar & Co., 30 Church Street, *New York City.*

MILLER, H. S., general manager, Plowman Tractor Co., *Waterloo, Iowa.*

MORTON, ALLEN WELLER, chief engineer, American Hammered Piston-Ring Co., *Baltimore.*

MORRIS, VICTOR ROSS, student, Ohio State University, *Columbus, Ohio.*

PARISH & BINGHAM CORPORATION, *Cleveland.* (Affiliate Membership)

PARROTT, R. B., secretary and treasurer, Service Products Corporation, *Indianapolis.*

PETTEBONE, ORLANDO R., draftsman, C. L. Best Tractor Co., *San Leandro, Cal.*

PHILIP, CHARLES W., chief engineer, Philip Motor Co., *San Francisco.*

PRESTON, NORMAN A., used car mechanical superintendent, Detroit Cadillac Motor Car Co., *New York City.*

RADNER, SAMUEL, student, Armour Institute of Technology, *Chicago.*

RANDOLPH, CHARLES L. W., student, Lewis Institute, *Chicago.*

REEVES, HUBERT A., student, California Institute of Technology, *Pasadena, Cal.*

ROEMMELE, HOWARD CARL, student, Stevens Institute of Technology, *Hoboken, N. J.*

ROHLOFF, DEWEY CHARLES, student, California Institute of Technology, *Pasadena, Cal.*

ROOT, RALPH C., engineer and sales manager, Service Products Corporation, *Indianapolis.*

SCHENCK, R. B., metallurgical engineer, Buick Motor Co., *Flint, Mich.*

SCHNEIDER, HAROLD P., student, Ohio State University, *Columbus, Ohio.*

SCHNEIDER, WARREN ARTHUR, student, California Institute of Technology, *Pasadena, Cal.*

SEBBES, LOUIS H., advertising copy writer, *Automotive Industries, Chicago.*

SHERRARD, JOE O., student, Ohio State University, *Columbus, Ohio.*

SKRIBA, LOUIS S., student, Armour Institute of Technology, *Chicago.*

SMALL, F. M., president, Martin-Parry Corporation, *York, Pa.*

SMELLIE, EDWIN FROST, student, University of Michigan, *Ann Arbor, Mich.*

SOWER, GEORGE W., student, Ohio State University, *Columbus, Ohio.*

STEINER, FELIX P., assistant tool designer, Detroit Cadillac Motor Car Co., *New York City.*

STETTINIUS, W. C., sales manager, American Hammered Piston-Ring Co., *Baltimore.*

STEVENSON, HORACE N., foreman, Mercer Motors, *Trenton, N. J.*

STROH, EDWIN R., vice-president, Stroh Casting Co., *Detroit.*

TETENS, RAYMOND E., assistant chief engineer, Earl Motors, Inc., *Jackson, Mich.*

THOMPSON, CHESTER A., general manager, Tire & Rim Association, *Cleveland.*

TRAUTMAN, HARRY A., foreman, Steel Products Co., *Cleveland.*

VAUGHAN, SAMUEL E., student, Leland Stanford, Jr., University, *Stanford University, Cal.*

VERPLANK, A. J., student, Armour Institute of Technology, *Chicago.*

VICKERS, WILLIAM HARRY, student, Armour Institute of Technology, *Chicago.*

VOORHEES, R. C., testing engineer, R. F. D. No. 3, *Ypsilanti, Mich.*

WALWORTH, RICHARD H., student, Armour Institute of Technology, *Chicago.*

WICKEL, RALPH O., student, Armour Institute of Technology, *Chicago.*

WILSON, EDWARD A., student, California Institute of Technology, *Pasadena, Cal.*

WOOLSON, HARRY THURBER, engineer, Zeder Motor Car Co., *Newark, N. J.*

WYZALEK, JOHN F., metallurgist, Hyatt bearings division, General Motors Corporation, *Harrison, N. J.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between April 10 and May 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

BACON, ELBRIDGE F. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 1038 East Huron Avenue.

CALDWELL, JESSE THOMAS (A) commercial engineer, National Lamp Works of General Electric Co., *Nela Park, Cleveland.*

DEFRANCE, SMITH J. (E S) student, University of Michigan, Ann Arbor, Mich., (mail) 27 Lansing Avenue, *Battle Creek, Mich.*

DUN, FAY A. (J) instructor in mechanical engineering department, Ohio State University, *Columbus, Ohio.*

ELLISON, LUKE V. (J) automotive service, Ellison Service, 222 North Main Street, *South Deerfield, Mass.*

FOLTZ, HAROLD H. (A) president and general manager, Foltz Truck Service Co., 78 North Summit Street, *Akron, Ohio.*

KEPLER, ARTHUR R. (A) sales engineer, Stewart-Warner Speedometer Corporation, Chicago, (mail) 2309 Chester Avenue, *Cleveland.*

STEVENS, S. B. (M) *Rome, N. Y.*

SYKES, GEORGE (A) general manager, Van Blerck Motor Co., *Monroe, Mich.*

TILDEN, MERRILL W. (A) president, Falls Motors Corporation, Sheboygan Falls, Wis., (mail) 163 West Washington Street, *Chicago.*

TUTTLE, J. H. (M) chief engineer, Westcott Motor Car Co., *Springfield, Ohio*, (mail) 1003 Garfield Avenue.

URBAN, WILLIAM C. (A) chief engineer, Hoyt Metal Co., *Granite City, Ill.*, (mail) 2247 B Street.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

INDEX TO VOLUME X, JANUARY-JUNE, 1922

	Pages
January	1-76
February	77-148
March	149-228
April	229-302
May	303-442
June	443-546

A

Abrasive wheel safety code 430
Absorption of water and oil in brake-linings 162
Activities of the Sections, S A E 72, 145, 223, 296, 431, 535
Adaptability of molybdenum steel to frame construction 340

Addresses

- At annual dinner 94
- At annual meeting 82, 83
- Bachman, B B 95
- Beecroft, David 82
- Grant, R H 149
- Horning, H L 83
- Kettering, C F 94
- Moulton, H G 165
- Quamme, E G 169

Adequate gating 54
Advantages of automatic rifle firing 144
Advantages to dealer of standardized body production 184
Advantages to user of standardized bodies 186

Aeronautic Division, S A E

- Activities 294
- Personnel 113, 291, 508
- Report at annual meeting 121

Aeronautic session at summer meeting 445

Aeronautics

- Balloon instruments and methods 61
- Wind-tunnel 146

Agricultural and financial situation improving 169

Agricultural Power Equipment Division, S A E

- Activities 294
- Personnel 113, 291, 477
- Report at semi-annual meeting 477

Agricultural production 52
Air-cooled engine development (C L Lawrance) 135, 405
Air-cooled engine, influence of gas velocity through the valves on the performance of an 254
Air-cooled versus water-cooled engines 140

Aircraft

- Air-cooled engine development (C L Lawrance) 135, 405
- Engine size and cooling 205
- Flighty reflections 466
- Method of developing engines 457
- Powerplant refinement 206
- Recent engine developments 204
- Some aspects of air-cooled cylinder design and development 231

Air measurement 321
Airplane engine session at annual meeting 78
Airplane performance formulas (E P Warner) 469

Airplanes

- Applications of formulas 474
- Battleships versus carriers 230
- Bomb dropping 63
- Ceiling formula 473
- Classification of performance formulas 470
- Climbing calculations 472
- Design of sights 63
- Estimation of ground speed 63
- Minimum and maximum speeds 470
- Passenger comfort 27
- Performance formulas 469
- Powerplant requirements 29
- Simplified methods of sighting 63
- Single and multi-engine 26
- Use of the wind tunnel 469

Air Service, cross-country flying by the 289
Alcohol for motor fuel 364
Allied debts 439
Alternative apparatus for determining volatility of fuels 19
American Engineering Standards Committee, representatives appointed 11
American marksmanship 134
American Petroleum Institute Fuel Session 1
Ampere-hour meter 503
Annealing-oven improvements 58

Annual Meeting, S A E

- Airplane engine session 78
- Automotive materials session 91
- Body engineering session 86
- Business session 78
- Carnival 94
- Dinner 94
- Fuel and engine session 92
- Lubrication session 87
- Meetings Committee report 85
- Membership Committee report 84
- Motor-truck transportation session 88
- Passenger-car session 93
- Reduced railroad fares 93
- Research department plans outlined 78
- Research session 90
- Reviewed 77
- Sections Committee report 85, 145
- Treasurer's report 85

Anti-knock compounds 204
Anti-knock research 356
Apparatus layout for gearset tests 194
Argentina and other competitors 170
Artificial-heat drying 391
Association, facility of 534
Atoms 62
Automatic charging of motive-power storage-batteries (H M Beck) 499

Automobiles

- Accessibility 263
- Adaptability of molybdenum steel to frame construction 340
- Basic materials in painting 13
- Body seating-dimensions 117, 394
- Bolts, cap-screws and nuts 264
- Brakes 273
- Care of the finish 15
- Chrome-molybdenum-steel applications from the consumer's viewpoint 384
- Color harmony 131
- Color psychology 131
- Color schemes 132
- Color values 132
- Crane spring-suspension 464
- Cushion height, depth and slope 117
- Dashboard instruments 265
- Decoration of interiors 133
- Depth of front and rear compartments 120
- Development history of top 366
- Drying and surfacing of paints and varnishes 15
- Engineering systems of application of paint 13
- Engineers part 98
- Fabrics 133
- General take-up adjustment 265
- Harmony in upholstery 131, 400
- Head-room 118
- Inaccessible parts necessitating dismantling 267
- Joy-riding over 98
- Manufacture and application of varnishes and paints 12, 388
- Materials in paints and varnishes 12
- Methods of application of paints 14
- More efficient 1
- New system of spring-suspension for 463
- Overhead camshaft engines 489
- Part-capacity production 98
- Passenger-car brakes 376
- Position of foot-rest, steering-wheel and controls 118
- Present practice of top 366
- Rear-axle spring-suspension 463
- Relation between fluid friction and transmission efficiency 193
- Seat width 118
- Simplicity of apparatus a prime consideration 23
- Some notes on the California top 366
- Standardization of control dimensions 120
- Stoppage ability 280
- Tire reaction 465
- Upholstery shape 117
- Use of pressed-steel parts 341
- What increased efficiency would mean 2
- Who must have 97

Automotive Industry

- Service-man's critical estimate of engineering 263
- Use of molybdenum steel in the 340

Automotive materials session 91
Autorifle, Thompson 134
Available supply of petroleum 187
Aviation sessions, coming 145

Aviation

- Commercial considerations 27
- Cross-country flying by the Air Service 289
- Danger in flying 25
- Essentials of transportation 30
- First incentive 466
- Function of the wing joint 467
- Government aid for 413
- Importance of versatility 467
- Landing-fields 25
- Passenger comfort 27
- Progress 79
- Single and multi-engine planes 26
- Trend of design 27
- Trend of development 25
- Truth about commercial 51

Axle and Wheels Division, S A E

- Activities 294, 435
- Personnel 113, 475, 508
- Report at semi-annual meeting 476
- Subject assigned 291

Axles, rear, spring-suspension 463

B

Bachman, B B, address 95

Ball and Roller Bearings Division, S A E

- Activities 70, 71, 72, 294, 298
- Personnel 113, 291, 508
- Report at annual meeting 121

Balloon instruments and methods 61
Barnard, D P, 4th, on Total Sensible Heats of Engine Fuels and Their Mixtures With Air 65
Basic industry 178
Basic machine elements, standards 271
Basis of optimism 150
Battleships versus airplane carriers 230
Bearings, friction tests of metal for 34
Beck, H M, on Automatic Charging of Motive-Power Storage-Batteries 499
Beecroft, David, on The Status of the Engineer in Automotive Economics 82
Belt-speed standards 271
Benefits of weak fuel-mixtures 313
Berry, O C, on Manifold Vaporization and Exhaust-Gas Temperatures 171, 402
Bibliography on brakes 508
Big inventories maintained 149
Blanks, rolled forging 45

Bodies

- Advantages to dealer of standardized 184
- Advantages to user of standardized 186
- Built according to specification 180
- Chassis builder constructing 179

Custom-built 181
Metal 184
Standardized sectional 182
Body engineering session 86
Body seating-dimensions (G E Goddard) 117, 394
Body service and garage equipment 164
Boiling points and specific gravity of gasoline 188
Bolts, cap-screws and nuts 264
Bomb, sights, drift 64
Bomb dropping 63
Bouncing-pin method of determining detonation 8
BOYD, T A, ON DETONATION CHARACTERISTICS OF SOME BLENDED MOTOR-FUELS 451
BOYD, T A, ON METHODS OF MEASURING DETONATION IN ENGINES 7, 374
Brake-drums, formula for size 280
Brake-linings 282

Brake-Linings

Absorption of water and oil 162
Coefficient of friction 155
Determination of relative durability 161
Developing a method for testing 153, 387
Endurance tests with a cooled drum 158
Equipment for tests 154
General considerations 154
Influence of oil and water on coefficient of friction 158
Rivet-holding ability 161
Severe-service test with uncooled drum 160
Brakes and safety 507

Brakes

Actuating means 279
Area formula 378
Bibliography 508
Car-stoppage ability 280
Design factors 275
Engine as a 283
Equalizers 281
Exposed and protected types 278
Four-wheel 378
Four-wheel and front-wheel 283
Future 283
Miscellaneous methods 286
Passenger-car (J Edward Schipper) 273, 376
Present 273
Propeller-shaft 377
Safety and 507
Servo principle of operation 285
Truck 289
Braking-power, uniform and effective 278
British automotive vehicle standardization 142
British experiments on engines 136
British ferrous-metal production 100
Budget, business 150
BULL, A A, ON OIL CONSUMPTION 513
Bullets, tracer and incendiary 220
Business and engineering 300
Business budget 150
Business cycle 52
Business has really turned the corner, how are we to know when 97

Business

How the engineer can help 149
In prospect, improved 152
Post-armistice 149
Sense essential 151
Business session at annual meeting 78
Buying by Germany 99

C

Calculation of pressure drop in the flame-front 361
Calculation of relation of pressure to flame travel 360
California top, some notes on the 366

Camshafts

Location of drive 491
Tappet-rods and overhead 489
Unusual forms of drive 495
Car-stoppage ability 280
Carbureters, characteristics 21
Carburizing and hardening of steel, effects of 50
Carnival at annual meeting 94
Case-hardening grades of steel 50

Castings

Adequate gating 54
Competing materials for 59
Elimination of shrinkage 60
Machinability 57
Pattern design 54
Pertinent facts concerning malleable-iron 53, 375
Physical characteristics 59
Possible defects 56
Ceiling formula 473
Central Europe, conditions in 166

Chain Division, S A E

Activities 70, 437
Personnel 113, 291, 508
Report at annual meeting 121
Charge for Transactions deferred 261
Chassis builder constructing bodies 179
Chassis lubrication 397
Chassis, special features of bus design 398
Chemical stability of fuels 22
Chicago fuel session 1

Chicago Service Dinner

Address by H G Moulton 165
Address by R H Grant 149
Chicago service meeting 163
Chrome-molybdenum-steel applications from the consumer's viewpoint. (C N Dawe) 47, 384
Chromium steels, corrosion of 414
CLAPPER, J S, ON THE TRACTOR MARKET 337
Classification of performance formulas 470
Climbing calculations 472
Coal, motor fuel from 414
Coal prices, freight rates and 170

Coefficient of Friction

Influence of oil and water on 158
Of brake-linings 155
Color harmony 131
Color psychology 131
Color schemes 132
Color values 132
Combustion-chamber design and turbulence 315

Combustion

Calculation of pressure drop in the flame-front 361
Calculation of relation of pressure to flame travel 360
Derivation of actual-reaction velocity 361
Derivation of displacement diagram 358
Molecular movements in closed systems 357
Pressure in the flame-front 359
Spectroscopic investigation of internal 383
Study of displacement diagram 359
Commercial-body supply and service (C M Manly and C B Veal) 179

Committees

Administrative, S A E, personnel 142
Meetings, S A E, report at annual meeting 85
Membership, S A E, report at annual meeting 84
Personnel of administrative 142
Personnel of 1922 Standards 113
Sections, S A E, report at annual meeting 85, 145
Standards, S A E, report at annual meeting 77
Compartments, depth of front and rear automobile 120
Competing materials for castings 59

Compression-Ratio

Effect on output, fuel-consumption and wall-temperature 243
Influence upon power output and efficiency 326
Conditions in this country 100
Conference at Washington 365
Constitution Committee, S A E, personnel 142
Continuous die rolling (G R Norton) 43, 374
Control dimensions, standardization of 120
Control of oil supply 518
Controls, position of 118

Cooling

Aircraft engine 205
Factors in engine 141
Progress in engine 140
Cooling surface on cylinder 242
Cooling systems on engines 81
Cooperation sought on volatility tests 20
Cooperative farm marketing 462
Corrosion of chromium steels 414

Costs

Molybdenum steel and manufacturing 341
Operating buses 398
Operating of die rolling 46
Cotton industry 368

Council Meetings

December, 1921 11
January, 1922 142
March 291
May 508
Cracking of gasoline 188
CRANE, H M, ON NEW SYSTEM OF SPRING-SUSPENSION FOR AUTOMOTIVE VEHICLES 463
Crane spring-suspension 464
Cross-country flying by the Air Service 289
Crowbars and economics 96
Current standardization work 69, 224, 298, 433
Cushion height, depth and slope 117
Custom-built bodies 181
CUTTER, JOHN D, ON USE OF MOLYBDENUM STEEL IN THE AUTOMOTIVE INDUSTRY 340

Cylinders

Contact effects and piston-ring 517
Cooling surface 242
Direct cooling versus cooling by conduction 232
Effect of compression-ratio on output, fuel-consumption and wall-temperature 243
Effect of spark-plug position on power output and fuel-consumption 254
Effects of mixture-strength and cooling air-supply upon temperature 232
Exhaust-valve cooling 252
Heat to be dissipated 231
Influence of size on performance 327
Influence of temperature on power output 327
Materials 248
Methods of finning 237
Some aspects of air-cooled design and development 231
Temperature distribution 232
Two-cycle construction 250
Types of 246
Types of head 242
Valve-gears 253
Valve-seat inserts in aluminum heads 250

D

Danger in flying 25
Dashboard instruments 265
DAWE, C N, ON CHROME-MOLYBDENUM-STEEL APPLICATIONS FROM THE CONSUMER'S VIEWPOINT 47, 384
Debts, allied 439
Decoration of car interiors 133
Defects, possible, in castings 56
Demand and supply 52
Demand, law of supply and 116
Deoxidation of steel 120
Depth of front and rear compartments 120
Derivation of actual-reaction velocity 361
Derivation of displacement diagram 358
Design factors of brakes 275
Determination of relative durability of brake-linings 161
Detonation 308
Detonation characteristics of some blended motor-fuels (Thomas Midgley, Jr, and T A Boyd) 451

Detonation

Bouncing-pin method of determining 8
Characteristics of some blended motor-fuels 451
Effects of 521
Fuel standards for use in measuring 9
Indicator method of determining 7
Listening method of determining 7
Methods of measuring in engines 7, 374
Temperature method of determining 8
Developing a method for testing brake-linings (S von Ammon) 153, 387
Development history of automobile top 366

Diagrams

Derivation of displacement 358
Study of displacement 359

Die Rolling

Continuous (G R Norton) 43, 374
Cost of operation 46
Equipment used 46
Forging blanks 45
Forming effected in one pass 45
Improvements in the art 43

Dinners

Addresses at annual 94
Chicago service 164
Minneapolis tractor 169
Direct cooling versus cooling by conduction 232

Displacement Diagram

Derivation 358
Study 359
Distribution of heat in a high-speed engine 327
Distribution of income from production 226
Diversified-farming requirements 177, 337
Division meetings, tentative schedule of S A E 292
Domestic progress 167
Drawing temperatures of steel, quenching and 48
Drift bomb-sights 64
Drivers and mechanics 427

Drives

Location of camshaft 491
Silent chain and spur gear 491
Spiral bevel gear 494
Unusual forms of camshaft 495
Drop-forging practice (J H Nelson) 207, 379
Dry and wet mixtures of fuels 192
Drying, artificial-heat 391

E

Economic balance necessary, return of 100
Economic efficiency of motor transport 418
Economics and crowbars 96
Economics of Motor Transport (M C Horine) 415

Economics

World a unit 166
World situation 165

Economy

Manufacturing 151
Possible effects of water injection on engine power and 290
Education, engineering 41
Effect of compression-ratio on output, fuel-consumption and wall-temperature 243
Effect of oil-return holes 515
Effect of phosphorus and sulphur in steel 291
Effect of side-clearance and ring motion 516
Effect of spark-plug position on power output and fuel-consumption 254
Effects of mixture-strength and cooling air-supply upon cylinder temperature 232
Effects of water injection on engine power and economy, possible 290
Efficiency under reduced loads 328

Efficiency

Economic, of motor transport 418
Gearset 198
Highway 419
Influence of compression-ratio on 326
Mechanical of engines 318
Relation between fluid friction and transmission 193, 372
Transport 419
Vehicle 420
What increased automobile, would mean 2
EGTVEDT, C L, ON FLIGHTY REFLECTIONS 466

Electric Vehicle Division, S A E

Activities 294, 434
Personnel 113, 291, 508
Subjects assigned 508

Electrical Equipment Division, S A E

Activities 69, 70, 71, 294, 298, 300, 433, 434, 436
Personnel 114, 433, 476
Report at annual meeting 122
Report at semi-annual meeting 476
Subjects assigned 508
Unaccepted recommendations 128

Electrification

Advantages of 42
Change will come piecemeal 42
Fuel saving about one-third 42
Problem one of finance 42
Railroad 42
Endurance tests with a cooled drum 158

Engine Division, S A E

Activities 70, 294, 434, 435
Personnel 114, 291, 476
Report at annual meeting 122
Report at semi-annual meeting 478
Subjects assigned 508
Unaccepted recommendations 129
Engineer, how can, help business 149
Engineering systems of application of paint 13

Engineering

Business and 300
Education 41
Service-man's critical estimate of 263

Engineers

As managers 16
In public discussion 120
International affiliation 83
Period 152
Status in automotive economics 82

Engines

Acceptance tests 458
Air-cooled development 135, 405
Air-cooled versus water-cooled 140
Aircraft size and cooling 205
Air measurement 321
Anti-knock compounds 204
Anti-knock research 356
As a brake 283
British experiments on air-cooled 136
British tests of air-cooled 136
Cooling factors 141
Cooling surface 242
Cooling systems 81
Cylinder materials 243
Detonation 308
Development procedure 457
Direct cooling versus cooling by conduction 232
Distribution of heat in a high-speed 327
Effect of compression-ratio on output, fuel-consumption and wall-temperature 243
Effect of mixture-strength and cooling air-supply upon cylinder temperature 232
Effect of spark-plug position on power output and fuel-consumption 254
Efficiency under reduced loads 328
External oil leaks and breather discharge 522
Flight and service tests 461
Governors 81
Heat to be dissipated 231
Importance of piston-ring fit 510
Indicators for high-speed 358
Influence of compression-ratio upon power output and efficiency 326
Influence of cylinder size on performance 327
Influence of cylinder temperature on power output 327
Influence of gas velocity through the valves on the performance of an air-cooled 254
Injection-type automotive 188
Internal-combustion 96
Internal-combustion characteristics 21
Internal-combustion fuels 187, 363
Internal energy of the working fluid 324
Lubricating systems 511
Manifold vaporization and exhaust-gas temperatures 171, 402
Mechanical efficiency 318
Method of developing aircraft 457
Methods of measuring detonation 7, 374
Molecular movement during combustion in closed systems 357
New designs 82
Over-dimensioned and over-compressed 204
Overhead camshaft passenger-car 489
Photographic recording of data 351
Pistons 264
Possible effects of water injection on power and economy 290
Progress in cooling 140
Recent aircraft developments 204
Recent research work on the internal-combustion 305
Relation between fluid friction and transmission efficiency 193, 372
Ring and cylinder contact effects 517
Silent chain and spur gear drives 491
Simplicity of automobile a prime consideration 23
Some aspects of air-cooled cylinder design and development 231
Spectroscopic investigation of internal combustion 218, 383
Spiral bevel gear drive 494
Standard test 458
Stationary internal-combustion 80
Stratification 311
Stratified charge 331
Sulzer marine diesel 112
Tappet-rods and overhead camshafts 489
Tear-down and inspection 460
Temperature distribution 232
Total sensible heats of fuels and their mixtures with air 65
Turbulence and combustion-chamber design 315
Types of air-cooled 138
Types of cylinder 246
Types of cylinder-head 242
Unusual forms of camshaft drive 495
Valve mechanisms 496
Equalizers for brakes 281
Equipment for testing brake-linings 154
Essentials of farm life 222
Estimation of ground speed 63

Europe

Conditions in central 166
Industrial conditions in 116
Evaporation, heat required 19
Exhaust-gas temperature tests 173
Exhaust-gas temperatures, manifold vaporization and 171, 402
Exhaust-valve cooling in cylinders 252
Expense, motor bus 203

Export Trade

German 450
Importance of 166
Mechanical inspection 64
Exposed types of brakes 278
External oil leaks and breather discharge 522

F

Fabrics 133
Facility of association 534
Factors controlling oil-pumping 509
Factory team-play 150
Farm animals, number and value of 295
Farm-implement finance 338
Farm implement, relation of tractor to 177
Farm marketing, cooperative 462
Farmers, organization by 178
Farmer's reward 456

Farming

Basic industry 178
Diversified requirements 177, 337
Essentials of life 222
Implement finance 338
Implement requirements 178
Row-crop cultivation 177
Finance, farm implement 338
Finance Committee, S A E, personnel 142
Financial situation improving, agricultural and 169
Finning, methods of 237
First incentive to aviation 466

Flame-Front

Pressure drop in 361
Pressure in 359
Flighty reflections (C L Egtvedt) 466
Flying, danger in 25
Foot-rest, position of 118

Forgings

Heat-treatment of finished 207
Testing finished 210
Forming effected in one pass 45

Formula

Airplane performance (E P Warner) 469
Application of, to airplanes 473
Brake area 378
Brake-drum size 280
Ceiling 473
Classification of airplane performance 470

Foundry difficulties 53
Foundry policy and purchasing agent 55
Four-wheel brakes 283, 378
Frames, molybdenum steel for 340

Frames Division, S A E

Activities 300
Personnel 114, 291, 508
Report at annual meeting 125

Freight rates and coal prices 170
Friction and viscosity (W H Herschel) 31, 369

Friction

Coefficient of, for brake-linings 155
Losses due to load 198
Testing of bearing metals 34

Front-wheel brakes 283

Fuel and Engine Session

Annual meeting 92
Summer meeting 446

Fuel-Consumption

Effect of compression-ratio on 243
Effect of spark-plug position on 254

Fuel standards for use in measuring detonation 9

Fuels

Alcohol for motor 364
Alternative apparatus for determining volatility 19
Available supply of petroleum 187
Benefits of weak mixtures 313
Better gasoline wanted 2
Boiling point and specific gravity 188
Characteristics 21
Chemical stability 22
Chicago session 1
Cracking 188
Determining partial vaporization 20
Detonation characteristics of some blended motor 451
Dry and wet mixtures 192
Ease of starting 18
85-per cent point 18
Gravity and viscosity 21
Heat required for evaporation 19
How can we measure the true volatility of motor? 6
Ignition 19
Internal-combustion engine 187, 363
Internal energy of the working fluid 324
Manifold vaporization and exhaust-gas temperatures 171, 402
Marketing policy 24
Mean volatility 308
Measurement of effective volatility 20
Motor from coal 414
Properties of materials used 452
Questionnaire results 22
Research work 305
Saturation point and famine 24
Saving about one-third with railroad electrification 42
Shale oil 191
Simplicity of apparatus a prime consideration 23
Substitute 189
Tested 172
Tests of total heats 66
Total sensible heats of engine, and their mixtures with air 65
Uniformity essential 21
Unsaturated hydrocarbons 6
Volatility the main dependency 21

Function of the wing joint 467
Future brakes 283

G

Galvanometer, string 352
Garage equipment and body service 164

Gasoline

Better wanted 2
Boiling points and specific gravity 188
Cracking 188
Mixers 82

Gating, adequate for castings 54
Gearset experiments 194

Gearset

Efficiency 198
Experiments with 194
Results of tests 196
Routine tests of 196

German export trade 450
Germany, buying by 99
GILKEY, W K, ON SPECTROSCOPIC INVESTIGATION OF INTERNAL COMBUSTION 218, 383
GODDARD, GEORGE, E, ON BODY SEATING-DIMENSIONS 117, 394
Goods bought only with goods 99
Government aid for aviation 413
Governors on engines 81
Grain, marketing 41
GRANT, R H, ON HOW THE ENGINEER CAN HELP BUSINESS 149
Gravity and viscosity 21
Gun, super-machine 220

H

HALLETT, CAPT G E A, ON METHOD OF DEVELOPING AIRCRAFT ENGINES 457
Hardening steel, carbonizing and, effects of 50
Harmony in car upholstery (R S Quaintance) 131, 400
Head-room 118

Heat

Distribution of, in a high-speed engine 327
Required for evaporation of fuels 19
To be dissipated 231
Total sensible, of engine fuels and their mixtures with air 65

Heat-treatment of finished forgings 207
...MSHAFT 489
...DARDS IN 270
...OF AIR-
...) DEVEL-
OPMENT 231
HERSCHEL, WINSLOW H, ON VISCOSITY AND FRICTION 31, 369
Highway engineering and transport instruction 272
Highway transportation as it affects the automotive engineer (E W Templin) 212

Highways and Roads

24
419
...ansport instruction 272
...it 425
...ction 425
...t affects the auto- 212
...Government, rep- 11
...S A E, personnel 291
271
...ONOMICS OF MOTOR 415
...NTERNATIONAL AF-
...EERS 83
172
...A E, personnel 142
...when business has
...rner (A R Marsh) 97
...an help business 149

I

Idle working people 99

Ignition

Characteristics 21
Difference in fuels 19
Forms of 80

IKERT, B M, ON SERVICE-MAN'S CRITICAL ESTIMATES OF AUTOMOTIVE ENGINEERING 263
Illumination of buses 397
Impact tests of tires 214
Importance of export trade 166
Importance of piston-ring fit 510
Importance of versatility 467
Improved business in prospect 152
Inaccessible parts necessitating dismantling 267

Income

Distribution from production 226
Rural and urban 101

Indicator method of determining detonation 7
Indicators for high-speed engines 353
Industrial conditions in Europe 116
Industrial unemployment 224
Industry in Middle West 176
Industry, welfare work 468
Influence of compression-ratio upon power output and efficiency 326
Influence of cylinder size on performance 327
Influence of cylinder temperature on power output 327
Influence of gas velocity through the valves on the performance of an air-cooled engine 254
Influence of oil and water on coefficient of friction of brake-linings 158
Influence of oil viscosity and effects of dilution 521
Injection-type automotive engine 188

Inspection

Mechanical, in export trade 64
Raw stock 207

Instruments and methods, balloon 61
Interchangeable manufacture 143
Internal-combustion engine 96
Internal-combustion engine fuels (C A Norman) 187, 363
Internal energy of the working fluid 324
International affiliation of engineers (H L Horning) 83
Intersection athletics at summer meeting 535
Inventories maintained, big 149

Iron and Steel Division, S A E

Activities 294, 299
Personnel 114, 291, 478
Report at annual meeting 125
Report at semi-annual meeting 479
Subject assigned 291

Iron, oxygen in 414

Isolated Electric Lighting Plant Division, S A E

Activities 294
Personnel 114, 291

J

JACKSON, WALTER, ON PAST, PRESENT AND FUTURE OF THE MOTOR-OMNIBUS 200, 395
Jitney competition 201
JONES, G DOUGLAS, ON THE RELATION OF THE TRACTOR TO THE FARM IMPLEMENT 177
Joy-riding over 98

K

KEGERREIS, C S, ON MANIFOLD VAPORIZATION AND EXHAUST-GAS TEMPERATURES 171, 402
Kettering, C F, address 94

L

Lack of improvement in railroad 221
Landing-fields 25
Law of supply and demand 116
LAWRANCE, C L, ON AIR-COOLED ENGINE DEVELOPMENT 135, 405
Legislation, motor bus 201
Letter ballot on adoption of standards 260

Lighting Division, S A E

Activities 69, 294
Personnel 114, 480
Report at annual meeting 126
Report at semi-annual meeting 480

Lines of necessary research 420
Listening method of determining detonation 7
Load, friction losses due to 198
Losses, friction, due to load 198

Lubricants

Characteristics of oil 21
Differences in oiliness of different, shown by tests 37
Incomplete film lubrication and the oiliness of lubricating oils 36
Oils 6
Systems in engines 511

Lubricants Division, S A E

Activities 70, 294
Personnel 114, 291, 533
Report at semi-annual meeting 533
Lubricating systems 511
Lubrication session at annual meeting 87

Lubrication

Chassis 397
Desirable features of oil-friction testing machines 39
Engine 82
Incomplete film and the oiliness of lubricating oils 36
Viscosity and friction 31, 369
Viscosity effect in the complete-film regime 31
Lug attachments 271

M

MacCoull, Neil, on Relation Between Fluid Friction and Transmission Efficiency 193, 372
Machinability of castings 57
Magneto mountings standardized 270
Malleable-iron castings, pertinent facts concerning (Enrique Touceda) 53
Managers, engineers as 16
Manifold vaporization and exhaust-gas temperatures (O C Berry and C S Kegerreis) 171, 402

Manifolds

Vaporization and exhaust-gas temperatures 171, 402
Hot-spot 172
Manly, C M, on Commercial-Body Supply and Service 179
Manufacture and application of automobile varnishes and paints (L V Pulsifer) 12, 388
changeable 143
nomy 151
41
ow Are We to Know Has Really Turned
97
Mean volatility 308
Mechanical efficiency 318
Mechanical inspection in export trade 64
Mechanical standardization 5

Meetings

Annual, S A E, reviewed 77
Chicago service 163
Council, S A E:
December, 1921 11
January, 1922 142
March 291
May 508
Minneapolis tractor 167
S A E Council:
December, 1921 11
January, 1922 142
March 291
May 508
Standards committee 121
Summer, announced 211, 229, 345
Tentative schedule of division 292

Meetings Committee

S A E, personnel 142
Report at annual meeting 85
Membership, increase of 84

Membership Committee, S A E

Personnel 142
Report at annual meeting 84
Membership roster, distribution 109
Membership roster to be maintained in prior form 269
Metal bodies 184
Method of controlling oil-pumping, novel 512
Method of developing aircraft engines (Capt George E A Hallett) 457
Methods of finning 237
Methods of measuring detonation in engines (Thomas Midgley, Jr, and T A Boyd) 7, 374
Methods of road construction 425
Methods of testing oil consumption 514
Middle West 176
Midgley, Thomas, Jr, on Detonation Characteristics of Some Blended Motor-Fuels 451
Midgley, Thomas, Jr, on Methods of Measuring Detonation in Engines 7, 374
Midgley, Thomas, Jr, on Molecular Movements During Combustion in Closed Systems 357
Midgley, Thomas, Jr, on Spectroscopic Investigation of Internal Combustion 218, 383
Minneapolis tractor meeting 167
Minneapolis Tractor Show, S A E, standards exhibit at 225
Miscellaneous braking methods 286
Mixers, gasoline 82
Moisture-content of wood 392
Moisture in wood 348
Molecular movements during combustion in closed systems (Thomas Midgley, Jr) 357
Molybdenum steel and manufacturing costs 341
Molybdenum-steel applications from the consumer's viewpoint, chrome 47, 384
Molybdenum-steel usage 47

Motorboat Division, S A E

Activities 294, 300, 437
Personnel 114
Subjects assigned 508
Motorboat field 80
Motorbus session at summer meeting 445
Motorcycle Division, S A E, personnel 114
Motor fuel from coal 414

Motor-Omnibuses

Competition 201
Expense 203
Future of 202
Legislation 201
Overland 201
Present of 200
Rates of fare 202
Motor-truck transportation session at annual meeting 88

Motor Vehicles

Advantages of standardized bodies 184
Automatic charging of storage-batteries 499
Bodies built to specification 180
British standardization 142
Chassis builder constructing bodies 179
Chassis lubrication 397
Commercial-body supply and service 179
Custom-built bodies 181
Detonation characteristics of some blended fuels 451
Drivers and mechanics 427
Economic efficiency 418
Economics of transport 415
Efficiency 420
Future of omnibus 202
Illumination of buses 397
Jitney competition 201
Lines of necessary research for transport 420
Metal bodies 184
Municipal operation of buses in New York City 398
Noise measurements 198
Omnibus legislation 201
Operating costs of buses 398
Overland omnibus 201
Past, present and future of the motor-omnibus 200, 395
Pneumatic tires 426
Present of omnibus 200
Special features of bus chassis design 398
Standardization of commercial cars and trucks 186
Standardized sectional bodies 182
Moulton, H G, address 165
Multi-engine airplanes 26
Municipal operation of buses in New York City 398
Myers, C T, on Paint Protection for Wood 348

N

Nelson, J H, on Drop-Forging Practice 207, 379
New system of spring-suspension for automotive vehicles (H M Crane) 463
Noise measurements 198

Nomenclature Division, S A E

Activities 294, 437
Personnel 114, 291, 508

Non-Ferrous Metals Division, S A E

Activities 295
Personnel 115, 481, 508
Report at annual meeting 126
Report at semi-annual meeting 481
Norman, C A, on Internal-Combustion Engine Fuels 187, 363
Norton, G R, on Continuous Die Rolling 43, 374
Number and value of farm animals 295

O

Officers, S A E, for 1922 85, 102
Oil consumption (A A Bull) 513
Oil grooving 510
Oil-pumping (George A Round) 509

Oils

Consumption 513
Control of supply 518
Effects of side-clearance and ring motion 516
External leaks and breather discharge 522
Factors controlling pumping 509
Greater recovery of 6
Incomplete film lubrication and the oiliness of lubricating 36
Influence of viscosity and effects of dilution 521
Lubricating 6, 24
Lubricating characteristics 21
Novel method of controlling pumping 512
Pumping (G A Round) 509
Shale 191
Tests of consumption 514
Uniform testing-methods 5
Optimism, basis of 150
Organization by farmers 178
Ovens, improvements in annealing 58
Over-dimensioned and over-compressed engines 204
Overhead camshaft passenger-car engines (P M Heldt) 489
Overland motorbuses 201
Oxygen in iron 414

P

Paint protection for wood (C T Myers) 348

Paints

Artificial-heat drying 391
Basic materials in automobile 13
Care of automobile finish 15
Drying and surfacing automobiles 15
Engineering systems of application of automobile 13
Manufacture and application of automobile varnishes and 12, 388
Materials in 12
Methods of application of automobile 14
Protection for wood 348
Protectiveness 349

Parts and Fittings Division, S A E

Activities, 69, 71, 295, 433, 434, 435, 436, 437, 438, 439
Personnel 115, 433, 434, 484, 508
Report at annual meeting 127
Report at semi-annual meeting 484
Subjects assigned 508

Passenger-Car Body Division, S A E

Activities 69, 72, 295, 437
Personnel 115, 508, 532
Report at annual meeting 127
Report at semi-annual meeting 532
Subject assigned 508
Passenger-car brakes (J Edward Schipper) 273, 376

Passenger-Car Division, S A E

Activities 298, 435
Personnel 115, 291
Passenger-car engines, overhead camshaft 489

Passenger-Car Session

Annual meeting 93
Summer meeting 446
Passenger comfort in airplanes 27
Past, present and future of the motor-omnibus (Walter Jackson) 200, 395
Pattern design of castings 54
Personnel of 1922 Standards Committee 113
Pertinent facts concerning malleable-iron castings (Enrique Touceda) 53, 375
Petroleum, available supply 187
Phosphorus and sulphur in steel, effect of 291
Photographic recording of engine data (Augustus Trowbridge) 351

Physical Characteristics
Castings 59
Steel 44
Pistons 264
Piston-ring 514
Piston-ring and cylinder contact effects 517

Piston Rings
Cylinder contact effects 517
Effect of oil-return holes 515
Effects of side-clearance and motion 516
Importance of fit 510
Oil grooving 510
Thin 516

Pistons
Experiments 319
Slipper aluminum 331
Pneumatic tires 426
Pneumatic truck tire 214
Position of foot-rest, steering-wheel and controls 118
Position of United States 166
Post-armistice business 149

Power
Influence of compression-ratio on 326
Influence of cylinder temperature on output 327
Possible effects of water injection on engine economy and 290

Power Output
Effect of compression ratio on 243
Effect of spark-plug position on 254

Powerplant
Aircraft, refinement 206
Requirements in airplanes 29
Pressure in the flame-front 359
Prices, freight rates and coal 170

Production
Agricultural 52
British ferrous-metal 100
Distribution of income from 226
Organization 224
Part-capacity, of automobiles 98
Progress in aviation 79
Progress in cooling engines 140
Propeller-shaft brakes 377
Propellers, test apparatus for models 534
Protected types of brakes 278
Protectiveness of paint 349
Publication Committee, S A E, personnel 142
Publications of interest to S A E members 73, 430
PULSIFER, L V, ON MANUFACTURE AND APPLICATION OF AUTOMOBILE VARNISHES AND PAINTS 12, 388
Purchasing agent, foundry policy and 55

Q

QUAINTANCE, R S, ON HARMONY IN CAR UPHOLSTERY 131, 400
Quamme, E G, address 169
Quenching and drawing temperatures of steel 48

R

Radiator Division, S A E, personnel 115, 291, 508
Railroad accommodations for summer meeting 449
Railroad electrification 42
Railroad transportation to summer meeting 346, 448

Railroads
Lack of improvement 221
Reduced fares for annual meeting 93
Rear-axle spring-suspension 463
Recent aircraft engine developments (C Fayette Taylor) 204
Recent research work on the internal-combustion engine (Harry R Ricardo) 305
Recovery in wheat-producing territory 170
Relation between fluid friction and transmission efficiency (Neil MacCoull) 193, 372
Relation of the tractor to the farm implement (G D Jones) 177
Reports of Divisions to Standards Committee 475

Reports
Divisions to Standards Committee 475
Meetings Committee, S A E, at annual meeting 85
Membership Committee, S A E, at annual meeting 84
Progress at semi-annual meeting on standards 475
Sections Committee, S A E, at annual meeting 85, 145
Standards Committee Division 475
Standards Committee, S A E, report at annual meeting 77
Treasurer's at annual meeting 85
Requisite conditions today 150
Research information service 111

Research Session
Annual meeting 90
Summer meeting 446
Research topics and suggestions 507

Research
Alcohol for motor fuel 364
Anti-knock 356
Fuel 305
Greater recovery of oil 6
Information service 111
Lines of necessary for motor transport 420
Paint protection for wood 350
Recent work on the internal-combustion engine (H R Ricardo) 305
Suggested problems for 290
Research Department, S A E, plans outlined 78
Return of economic balance necessary 100
RICARDO, HARRY R, ON RECENT RESEARCH WORK ON THE INTERNAL-COMBUSTION ENGINE 305
Rifle, advantages of automatic, firing 144
Rivet-holding ability of brake-linings 161
Roads 24

Roads and Highways
Determining type 24
Efficiency 419
Engineering and transport instruction 272
Limitation of weight 425
Methods of construction 425
Transportation as it affects the automotive engineer 212
Rolled forging blanks 45
Roster of membership to be maintained in prior form 269
ROUND, GEORGE A, ON OIL-PUMPING 509
Row-crop cultivation 177
Rural and urban incomes 101

S

S A E
Activities of the Sections 72, 145, 223, 296, 431, 535
Annual meeting reviewed 77
Automotive materials session at annual meeting 91
Body engineering session at annual meeting 86
Carnival at annual meeting 94
Chicago service meeting 163
Council meetings:
December, 1921 11
January, 1922 142
March 291
May 508
Current standardization work 69, 224, 433
Fuel and engine session at annual meeting 92
Fuel and engine session at summer meeting 446
Lubrication session at annual meeting 87
Minneapolis tractor meeting 167
Motor-truck transportation session at annual meeting 88
Officers for 1922 85, 102
Passenger-car session at annual meeting 93
Passenger-car session at summer meeting 446
Reduced railroad fares for annual meeting 93
Reports of divisions to Standards Committee 475
Research session at annual meeting 90
Research session at summer meeting 446
Sections activities 72, 145, 223, 296, 431, 535
Sections officers 535
Standards committee report 77
Standards exhibit at the Minneapolis Tractor Show 225
Summer meeting announced 211, 229, 345
Summer meeting program 447
Safety code, abrasive wheel 430
Sales territory, selecting 151
Saturation point and fuel famine 24
SCHIPPER, J EDWARD, ON PASSENGER-CAR BRAKES 273, 376
Science 230
Screw sizes and lug attachment 271

Screw Threads Division, S A E
Activities 295
Personnel 115, 524
Report at annual meeting 128
Report at semi-annual meeting 524
Subjects assigned 508
Screws, sizes 271
Seat width 118

Sections, S A E
Activities 72, 145, 223, 296, 431, 535
Athletics at summer meeting 535
New officers 535

Sections Committee, S A E
Personnel 142
Report at annual meeting 85, 145
Segregation of raw stock 207
Selecting sales territory 151
Service 68
Service-man's critical estimate of automotive engineering (B M Ikert) 263
Servo principle of operation 285
Severe-service test with uncooled drum 160
Shale oil 191
Sighting, simplified methods of 63

Sights
Design of bomb dropping 63
Drift bomb 64
Silent chain and spur gear drives 491
Single-engine airplanes 26
Slipper aluminum pistons 331
Some aspects of air-cooled cylinder design and development (S D Heron) 231
Some notes on California top (P W Steinbeck) 366
Spark-plug, effect of position on power output and fuel-consumption 254
Special trains and pullmans for summer meeting 449
Specifications, bodies built according to 180
Spectroscopes 219
Spectroscopic analysis 219
Spectroscopic investigation of internal combustion (Thomas Midgley, Jr, and W K Gilkey) 218, 383
Spectroscopy 218

Speed
Estimation of ground 63
Minimum and maximum of airplanes 470
Spiral bevel gear drive on engine 494
Sports events at summer meeting 448
Sports program at summer meeting 449
Spring suspension and steering 215

Springs
Crane suspension 464
New system of suspension for automotive vehicles 463
Rear-axle suspension 463
Suspension and steering 215
Tire reaction 465

Springs Division, S A E
Activities 295
Personnel 115, 438, 532
Report at semi-annual meeting 532
Subjects assigned 438
Standard basic machine elements 271
Standardization 450

Standardization
Belt-speeds 271
British automotive vehicle 143
Commercial cars and trucks 186
Control dimensions 120
Current work 69, 224, 298, 433

General considerations 272
Hitches 271
Magneto mountings 270
Parts and fittings in oil field 5
Sectional bodies 182

Standards

Basic machine elements 271
Exhibit at Minneapolis Tractor Show 225
First day of summer meeting devoted to 445
Hitches and belt-speeds 271
Letter ballot on adoption of 260
Steel and other 271
Value of, in tractor manufacture 270

Standards Committee, S A E

Attendance at meeting 130
Division reports at semi-annual meeting 475
Letter ballot on adoption of standards 260
Meeting 121
Personnel for 1922 113
Report at annual meeting 77
Reports of divisions 475
Tentative schedule of division meetings 292
Starting, ease of 18

Stationary Engine Division, S A E

Activities 295
Personnel 115, 484
Report at semi-annual meeting 484
Stationary internal-combustion engines 80
Status of the engineer in automotive economics (David Beecroft) 82
Steel and other standards 271

Steels

Adaptability of molybdenum to frame construction 340
Case-hardening grades 50
Chrome-molybdenum, applications from the consumer's viewpoint 47, 384
Continuous die rolling 43, 374
Corrosion of chromium 414
Deoxidation of 120
Drop-forging practice 207, 379
Effects of carbonizing and hardening 50
Effect of phosphorus and sulphur in 291
Inspection of raw stock 207
Methods of testing 48
Molybdenum and manufacturing costs 341
Molybdenum usage 47
Physical characteristics 44
Quenching and drawing temperatures 48
Segregation of raw stock 207
Standard specifications 271
Use for other pressed parts 341
Use of molybdenum in the automotive industry 340
Steering-wheel, position of 118
STEINBECK, P W, ON SOME NOTES ON THE CALIFORNIA TOP 366

Storage Battery Division, S A E

Activities 295
Personnel 115, 508

Storage-Batteries

Ampere-hour meter 503
Automatic charging of motive-power 499
Methods of cut-off 502
Modern 500
Principles 500
Two-step charge 504
Stratification 311
Stratified-charge engines 331
String galvanometer 352
Student 363
Study of displacement diagram 359
Substitute fuels 189
Suggested problems for research 290
Sulphur in steel, effect of phosphorus and 291
Sulzer marine diesel engine 112

Summer Meeting, S A E

Announcement 211, 229, 345
First day devoted to standards 445
Fuel and engine session 446
General plan 445
Inter-section athletics 535
Motorbus and aeronautic sessions 445
Passenger-car session 446
Program 445
Railroad accommodations 449

ation 346, 448
446
pullmans 449
inment 347
230
448
449
345
of papers 448
Super-machine-gun 220
Supply and demand, law of 116

T

265
camshafts 489
165
ECENT AIR-
NTS 204
150
engines 460
ner meeting 345
cylinders 232
rmining de-
8

Temperature

Cylinder, and power output 327
Drawing, steel 48
Effects of mixture-strength and cooling air-supply upon cylinder 232
Exhaust-gas tests 173
Manifold vaporization and exhaust-gas 171, 402
Quenching and drawing, steel 48
TEMPLIN, E W, ON HIGHWAY TRANSPORTATION AS IT AFFECTS THE AUTOMOTIVE ENGINEER 212
Tentative schedule of division meetings 292
Test apparatus for propeller models 534

Tests

and oil in brake-
162
es 458
ler models 534
136
oil-friction test-
39
elative durability
161
for brake-linings 153, 387
Differences in oiliness of different lubricants shown by 37
Endurance with a cooled drum 158
Equipment for brake-lining 154
Exhaust-gas temperature 173
Finished forgings 210
Flight and service of engines 461
Friction of bearing metals 34
Fuel 172
Gearset 194
Heat of fuel 66
Hot-plate 172
Impact of tires 214
Measurement of effective volatility of fuels 20
Methods of testing steel 48
Oil consumption 514
Pistons 319
Result of gearset 196
Routine for gearset 195
Service 38
Severe-service with uncooled drum 160
Standard for engines 458
Steel, methods of 48
Uniform methods of oil 5
Thompson autorifle 134
Tire and Rim Division, S A E, report at annual meeting 129

Tires

Impact tests of 214
Pneumatic 426
Pneumatic truck 214
Reaction 465
Total sensible heats of engine fuels and their mixtures with air (R E Wilson and D P Barnard, 4th) 65
TOUCEDA, ENRIQUE, ON PERTINENT FACTS CONCERNING MALLEABLE IRON CASTINGS 53, 375
Tracer and incendiary bullets 220
Trackless trolley car 396
Tractor Division, S A E, report at annual meeting 128
Tractor engineering 79
Tractor market (J S Clapper) 337
Tractor meeting, Minneapolis 167

Tractors

Distributors' opinions 339
Engineering 79
Magneto mountings standardized 270
Market 337
Relation to farm implement 177
Requirements 177
Statistical consideration 338
Steel and other standards 271
Suitability 339
Value of standards in manufacture 270

Traffic and Transportation

Economic efficiency of motor 418
Economics of motor transport 415
Efficiency 419
Essentials of air 30
Highway as it affects the automotive engineer 212
Highway engineering and instruction 272

Transactions

Charge for, deferred 261
Distribution 109
Transition point 34

Transmission Division, S A E

Activities 295, 434
Personnel 115, 291, 434, 508
Report at annual meeting 128
Transmission, relation betweeen fluid friction and efficiency 193, 372
Treasurer's report at annual meeting 85
Trend of aviation development (J G Vincent) 25
Trolley-car, trackless 396
TROWBRIDGE, AUGUSTUS, ON PHOTOGRAPHIC RECORDING OF ENGINE DATA 351

Truck Division, S A E

Activities 70, 295
Personnel 116
Report at annual meeting 128
Subject assigned 508
Trucks, brakes 289
Truth about commercial aviation 51
Turbulence, combustion-chamber design and 315
Two-step charge 504
Types of engines 138

U

Unemployment, industrial 224
Uniform and effective braking-power 278
United States, position of 166
Unusual forms of camshaft drives 495
Upholstery, harmony in car 131, 400
Upholstery shape 117
Urban and rural incomes 101
Use of molybdenum steel in the automotive industry (John D Cutter) 340

V

Value of farm animals, number and 295
Value of standards in tractor manufacture (P M Heldt) 270
Valve-gears 253
Valve-seat inserts in aluminum cylinder heads 250

Valves

Adjustment 265
Mechanisms 496
Vaporization and exhaust-gas temperatures, manifold 171, 402
Vaporization, determining partial 20

Varnishes

Artificial-heat drying 391
Care of automobile finish 15
Manufacture and application of automobile paints and 12, 388
Materials 12
VEAL, C B, ON COMMERCIAL-BODY SUPPLY AND SERVICE 179
Velocity, actual reaction 361
Versatility, importance of 467
VINCENT, J G, ON TREND OF AVIATION DEVELOPMENT 25
Viscosity and friction (W H Herschel) 31, 369

Viscosity

Effect in the complete-film-lubrication regime 31
Estimation at one temperature from observed viscosity at another temperature 33

Gravity and 21
Influences of oil and effects of dilution 521
Relation of absolute to the readings of instruments ordinarily used 32

Volatility

Alternative apparatus for determining 19
Main dependency 21
Mean 308
Measurement of effective 20
VON AMMON, S, ON DEVELOPING A METHOD FOR TESTING BRAKE-LININGS 153, 387

W

Wages 52
WARNER, E P, ON AIRPLANE PERFORMANCE FORMULAS 469
Washington Conference 365
Weight, limitation on roads 425
Welfare work 468
Wheat-producing territory, recovery in 170

Wheels

Abrasive safety code 430
Moisture-content of wood 392
Who must have automobiles 97
WILSON, R E, ON TOTAL SENSIBLE HEATS OF ENGINE FUELS AND THEIR MIXTURES WITH AIR 65
Wind-tunnel 146
Wind-tunnel, use of 469
Wing joint, function of 467

Woods

Moisture-content of 392
Moisture in 348
Paint protection for 348
Protectiveness of paint 349
World an economic unit 166
World economic situation 165
Written discussion of papers at summer meeting 448